

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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NO. 1

H. F. NEWALL, Esq., M.A., F.R.S., PRESIDENT, in the Chair.

Harold A. H. Christie, M.A., Royal Observatory, Greenwich, S.E.;

Bertram Francis Eardley Keeling, The Observatory, Helwân, near Cairo, Egypt; and

Frederick Alexander Lindemann, Sidholm, Sidmouth, Devon, were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Henry Boase Austin, J.P., Government Buildings, Bloemfontein, Orange River Colony, South Africa (proposed by R. T. A. Innes);

W. Geoffrey Duffield, Physical Laboratory, Manchester University (proposed by Arthur Schuster);

W. Earnshaw Etzel, B.Sc., Litt.L., M.S.M.F., Professor of Science, St Bernard's, Rochester, N.Y., U.S.A. (proposed by William R. Brooks);

John M. Field, 1 Hart Street, Edinburgh (proposed by William Peck);

James D. Maddrill, Ph.D., International Latitude Observatory, Ukiah, California, U.S.A. (proposed by H. C. Plummer);

William Henry Rees, B.Sc., Mathematical Master, County School, Pontypridd, 2 Graigeven Place, Pontypridd, South Wales (proposed by Richard Kerr);

Thomas James Forrester Smith, Newstead, Wavertree, near Liverpool (proposed by F. W. Longbottom); and

Captain James Weir, F.R.G.S., Examiner of Masters and Mates in Navigation and Seamanship to the Board of Trade, 5 Clive Crescent, Penarth, Glamorgan, South Wales (proposed by Albert Taylor).

One hundred and sixty-nine presents were announced as having been received since the last meeting, including, amongst others :—

W. W. Bryant, *History of Astronomy*; S. W. Burnham, *General Catalogue of Double Stars* (2 vols.); and Sir G. H. Darwin, *Scientific Papers*, vol. i., presented by the authors; Galileo, *Opere*, Edizio nazionale, vol. iii. part 2 and vol. xix., presented by the Italian Government; Lady Huggins, *Memoir of Agnes and Ellen Clerke*, presented by the author; Oxford *Astrographic Catalogue*, vol. iii.; *Observatoire de Paris*, *Atlas Photographique de la lune* (Loewy and Puiseux), fasc. 9; and Perth Observatory, *Western Australia, Catalogue of 420 standard stars*, presented by the Observatories; Sir N. Lockyer, *Report of the Eclipse Expedition to Majorca*, presented by the Solar Physics Committee.

Astrographic Chart; 134 charts (Algiers, Bordeaux, Paris, and San Fernando), presented by the French Government; 23 charts, presented by the Tacubaya Observatory, Mexico; and 76 charts, presented by the Royal Observatory, Greenwich.

Three transparencies of the moon from negatives of M. Puiseux, presented by Mr Knobel; 9 transparencies of the northern Milky Way, presented by Professor Max Wolf.

Medal to commemorate the Benjamin Franklin bicentenary (bronze), presented by the American Philosophical Society.

Spectroscopic Observations of Cyanogen in the Solar Atmosphere and in Interplanetary Space. By H. F. Newall, M.A., F.R.S.

The presence of cyanogen in the atmosphere of the Sun seems to be indicated by the distinct appearance of the cyanogen absorption bands at wave-length 3883 in the solar spectrum. But, so far as I am aware, no definite observations have been directed to settle the possible doubt as to whether the cyanogen is confined to the solar atmosphere. The possible alternatives are that it may be in the Earth's atmosphere, or in space between the Sun and the Earth.

[*Note.* Nov. 11.—Professor Dyson has kindly called my attention to evidence which had escaped my memory and is conclusive as to the presence of cyanogen in the chromosphere. Sir N. Lockyer found CN bands in the flash spectrum of the chromosphere photographed in India in 1898 (*Phil. Trans. R.S.*, vol. cxvii. A., p. 202, and *Mem. R.A.S.*, vol. liv., App. p. [52]), and Professor Dyson himself found them in his observations in Sumatra in 1901 (*Phil. Trans.*, vol. ccvi. A., p. 438, and *Mem. R.A.S.* lvii., App. [36]). I have accordingly modified one or two of the statements in the paper.]

During the past summer I have made some observations in attempting to elucidate this point. The method adopted consisted in photographing side by side on one photographic plate two solar

spectra taken successively in the light coming from the east and from the west ends of the equatorial diameter of the Sun. Lines of truly solar origin should show relative displacement in the two spectra in consequence of the difference of velocity in the line of sight arising from the Sun's rotation. This is a form of the well-known method of Cornu for distinguishing between lines of solar and lines of telluric origin.

In the result I find that my photographs show displacement of the cyanogen bands similar to that exhibited by neighbouring lines of iron and other vapours. There are, however, also evidences in the photographs that there is a trace of superposed cyanogen bands exhibiting displacements other than those attributable to the Sun's rotation. Thus the evidence so far accumulated shows that there is cyanogen in the Sun's atmosphere rotating with the Sun, and there is also cyanogen between the Earth's surface and the Sun showing spectroscopic displacements that may be attributed to independent motion.

Before passing on to give the evidence collected, it may be well to give some considerations which may be held to justify the inquiry as to the seat of cyanogen absorption. I recognise the highly speculative nature of some of them, but I beg leave to set them forth, in company with the statement of several newly observed facts, which go some way towards justifying speculation.

One of the most marked features of the spectrum of comets is the bright bands of cyanogen at 3883 first discovered by Sir W. Huggins. It has generally been held that this incandescent cyanogen and the other carbon compounds evidenced by cometary spectra are emitted from the comet's head, driven out under the influence of the Sun's radiation. On this view the observed fact that periodic comets seldom display brilliant tails receives the explanation that each successive return of a comet to perihelion reduces the quantity of vapour in the possession of the comet's nucleus; such vapours, then, are set free in interplanetary space and seem to be spread out, mainly in the plane of the comet's orbit, under the action of repulsive forces. The old view that the freed vapours are swept up by the gravitative attraction of the planets and the Sun is now being replaced by the modern view that radiation-pressure drives the larger aggregates of molecules or ions outwards from the Sun. Schwarzschild's work has shown that things as small as molecules cannot, as such, be repelled by radiation-pressure. It is generally held that molecules are of linear dimensions of the order of 10^{-8} cms., whilst the wave-length of green light is of the order 5×10^{-5} cms. And Schwarzschild has shown that things smaller than a tenth of the wave-length of the radiation are more attracted by gravitation to the Sun than repelled by the pressure of the Sun's radiation.

But it is held that a great deal of the display of comets' tails is due to illuminated dust as is shown both by the spectrum and also by the polariscopic phenomena observed by Prazmowski and others. Here again the dimensions of particles giving the polarisa-

tion effects afford some difficulties; but it might be held that the gases, which the spectroscope shows to be present in the tail, are carried out by the repelled dust. Arrhenius, however, as far as I understand his present views, is ready to regard the molecules of gases and vapours as grouped in aggregates large enough to bring them under the sway of radiation-pressure.

The work of Deslandres and Bernard on the spectrum of Daniel's comet 1907 *d* (*C.R.*, cxlv. 445) shows that bands of some gaseous substances were visible in the tail at 45 minutes of arc from the nucleus in the middle of August; and I learn from a letter from Mr. Evershed that, at Kodaikámal, he and Mrs. Evershed have succeeded in photographing the same comet with a prismatic camera, with the following results:—"The hydrocarbon bands extend a long way up into the tail, whilst the cyanogen bands near 3883, although the most brilliant radiations in the comet spectrum, are concentrated round the head."

Now, both in the case of the absorption bands of cyanogen seen in the solar spectrum and in the emission bands of the same vapour seen in the cometary spectrum, a peculiar feature is that the ultra-violet bands at 3883 are the most marked, and that the blue and violet bands are far more feebly seen than under certain conditions attainable in the laboratory (Liveing and Dewar, *Proc. R.S.*, xxx. 494). Some years ago I made a series of observations on the spectra of carbon compounds commonly present in vacuum tubes. My observations (unpublished) related chiefly to phenomena in electrodeless discharges brought about by Professor J. J. Thomson's electro-magnetic method (*Phil. Mag.*, 1891, vol. xxxii. p. 321, and *Proc. Roy. Inst.*, xiv. p. 243), wherein a tube or bulb of considerable diameter, ranging from about 12 mm. to 100 mm., is surrounded by a few coils of thick wire, the ends of which are connected with two Leyden jars or plate condensers. The discharge of such charged condensers is accompanied by exceedingly rapid electrical oscillations, which give rise to induced oscillations (accompanied by luminosity) in the rarefied gas in the enclosed tube. The method made it possible to produce brilliant luminosity in the gas at much lower pressures than those then attainable in ordinary vacuum tubes provided with electrodes. The pressures measured were between 0.60 mm. and 0.005 mm. of mercury.

I will refer here only to two of the results indicated by my observations. One was that as the pressure was diminished the bands of nitrogen and cyanogen, which I specially studied, became faint and disappeared at the red end of the spectrum, whilst those in the violet and ultra-violet were left distinct, or even intensified. I found no case which did not conform with the generalisation, that as pressure is diminished the maximum intensity of the banded spectra is pushed towards the shorter wave-lengths—the electrical conditions being kept constant. The observations of Hasselberg and of Deslandres support this view with respect to nitrogen; and it would not be difficult to devise a set of experiments to decide whether my observations can be reconciled with those of Nutting

(*Astroph. Jour.*, xx. 131), which, so far as they go on these lines, seem to indicate an opposite conclusion for the much higher pressures between 1 mm. and 21 mm. At any rate my own (laboratory) experiments have led me to the belief that in the solar spectrum the evidence points to the conclusion that cyanogen is at low pressure. It is obvious that the pressure must be low in the case of a comet's tail extending several thousands (if not millions) of miles from the nucleus.

The other observation to which I now wish to refer was that the spectra of hydrocarbons and nitrocarbons were far the most easily elicited in such tubes and bulbs, and that the processes involved in the production of luminosity in the vapours could be started under conditions which proved instability, in the sense that the gas was luminous in regions of the vacuum bulb where the electromotive intensity (E.M.F. per cm.) was zero.

This observation suggested an alternative to the usually accepted view of the origin of the cyanogen, etc., in cometary spectra, as follows:—Is it not possible that the hydrocarbons, nitrocarbons, etc., which seem to be evidenced by the spectra of all comets, are *always* present in circumsolar space, and rendered incandescent by some processes connected either with the motion of the solid parts (including dust) of the head of the comet through the vapours, or with the emission of some influence from the comet head? Are we to say that all comets, wherever they may come from in the universe, and whatever their main material may be, always bring with them the cyanogen and hydrocarbons which give them luminosity? Or is it not more rational to say that the spectra of all comets are approximately similar, because they always find the same vapours spread in their path as they approach the Sun, and can only elicit the spectra of these vapours?

If we adopt this latter view, then, apart from the phenomena of repulsion, we have only to explain the production of luminosity, and variations in the intensity of it. And out of the embarrassing wealth of suggestions connected with the development of the corpuscular theory of matter, there is no difficulty in picking one or two modes of influence to which incandescence might be attributed. I will not dwell on this aspect, but will call attention to another mode of producing luminosity—wherein there is no obvious sign of high temperature—I mean the luminosity of air when it rushes through a small crack in the glass walls of a vacuum tube, a phenomenon that must be familiar to most of those who have been engaged in experimental study of such tubes. Two or three times I have been able to recognise the bands of nitrogen in the spectrum of the glow in such a crack. Now, such luminosity cannot be peculiar to nitrogen. If it is legitimate to assume that hydrocarbons and cyanogen would behave similarly, it is not a long step to assume that it is as likely that luminosity will arise when small specks of cometary dust or solid particles are rushing through the gas (possibly in a sensitive state), as that luminosity should be produced when the gas rushes past the walls of a small crack into vacuum.

However the luminosity may be produced, the absence of brilliant display in periodic comets might, on the hypothesis of the constant existence of the vapours in interplanetary space, be attributed to the gradual change in the surface of the solid parts of the head of the comet, or to the exhaustion of the emitted influence.

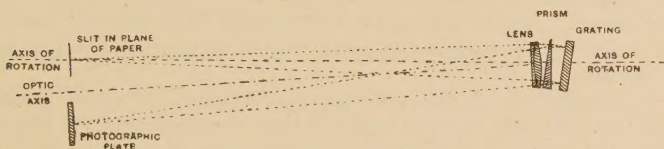
My present purpose is, however, not to elaborate views about comets' tails, but simply to point out that if one accepts radiation-pressure and the phenomena of the repulsion of comets' tails, one is driven to admit the existence of vapours and gases in circumsolar space, however difficult it may be to give account of their quantitative distribution in such space. The great extensions of the corona (as was pointed out by Huggins in his Bakerian Lecture, 1885), and the equally great extension of comets' tails, demand the admission that at any rate temporarily gases and vapours must exist in "free space." How long the clearing process lasts, which depends on the conflict between the pressure of radiation and the gravitative attraction of the Sun and the planets, is another matter.

It is difficult to devise crucial observations which would decide the points raised by these views. For it is to be expected that gases and vapours, if present at all, would be in such a turmoil of rotation round the Sun that the integrated effect of their absorption could hardly give defined lines or bands of absorption, except in the case of accidentally related motions in the vapours at different distances from the Sun. The best way to proceed seemed to be to make special observations of the cyanogen bands, and so learn whether there really are any peculiarities to be found in their behaviour. Professor Hale has pointed out (*Astroph. Jour.*, xxv. 310) that the cyanogen fluting at 3883 is very decidedly weakened at the limb of the Sun relatively to the centre of the disk. Humphreys has shown (*Astroph. Jour.*, xxvi. 28) that the lines of the cyanogen bands are not appreciably displaced in the spectrum of the electric arc, even at the highest pressures used by him (100 atmospheres).

The instrument used for the observations of the cyanogen bands is a new grating spectroscope made by the Cambridge Scientific Instrument Company, and recently mounted for solar observation at the Cambridge Observatory. It forms part of the installation which is in course of construction for solar work. The general form of the installation has been indicated in a previous paper communicated to the Society (*M.N.*, lxvii. p. 161.) The observatory is indebted for this equipment to the munificence of the late Frank McClean, F.R.S.

The spectroscope is of Littrow type, *i.e.* one and the same tube and object-glass serve both as collimator and camera, the slit and photographic plate being slightly separated in the focal plane of the common object-glass. The lens has an aperture of 4 inches [101 mm.], and is of focal length 14 feet [4267 mm.]. A Rowland

plane grating, with ruled surface $5 \times 3\frac{1}{2}$ inches [127×89 mm.] with 14,438 lines to the inch, is used to produce the spectrum. In order to allow of the use of spectra of high order without the troubles introduced by superposed spectra, a prism of small angle 5° and of circular aperture 4 inches [101 mm.] has been inserted, with its refracting edge perpendicular to the rulings of the grating between the grating and the object-glass. Both object-glass and prism are the work of Messrs Cooke & Sons of York, and are of excellent performance. Provision is made for tilting the spindle and frame, which hold the grating, about an axis parallel to the refracting edge of the prism; in this way any part of any spectrum is brought to the centre of the photographic plate, and the dispersion is such that the ordinarily superposed spectrum is thrown above or below. Then, on turning the grating about its axis of rotation, the succession of appearances in the field of view is such that the blue end of the spectrum is seen at the bottom of the field of view; as we turn towards the green, the spectrum mounts to the middle of the field; and on turning further, the red is to be seen at the top of the field. By the tilting of the spindle



on which the grating turns, any part of the spectrum can be brought to the middle of the field.

The instrument, which is of very rigid construction and weighs about 6 hundredweight (300 kilogrammes), has been mounted horizontally on roller bearings, which allow of easy rotation of the whole about a horizontal axis, so that the slit can be turned into any position angle. A position circle is provided, divided to half degrees. The axis on which the instrument turns coincides with the line joining the middle point of the slit to the middle point of the object-glass. In this way a horizontal pencil of rays incident from the proper direction on the centre of the slit always passes through the centre of the collimator-camera lens, whatever may be the position angle of the slit. The true optic axis passes through the focal plane at a point midway between the middle point of the slit and its image; this point thus describes a small circle round the middle of the slit as the whole instrument is rotated on its roller bearings. The middle point of the photographic plate similarly describes a concentric circle of twice the radius.

Black opaque diaphragms of the proper size have been inserted in the proper places between the slit and the object-glass, in order to prevent the light reflected from the surface of the lenses from falling on the spectrum on the photographic plate.

A convenient device has been added to limit the length of the slit used, and to allow of the juxtaposition of spectra in successive exposures on one and the same photographic plate; thus a spectrum of the east limb of the Sun can be photographed between two spectra of the west limb, or two spectra of the east limb can be alternated with two spectra of the west limb.

In the preliminary work with the instrument great care had to be exercised in overcoming the erratic performance of the grating; and in order to secure the defining power required for this work it was found necessary to limit the area of the ruled surface by means of diaphragms carefully placed. When all the ruled surface except a strip 5 inches wide and about $1\frac{3}{4}$ inches high was blocked out, it was found that excellent definition could be attained with full resolving power; and the exposures needed for photographing the cyanogen band at 3883 in the spectrum of the third order seldom exceeded a minute, and in a bright sky an exposure of 30 seconds was ample.

The photographs obtained with the instrument exhibit the spectrum with very open scale, and many of the close double lines even in the cyanogen band are well seen. The linear dispersion of the negatives is such that we have about 1.29 tenthmetres per millimetre. And it should be remembered that the total exposure of a plate in the instrument was completed generally in less than 3 minutes.

Examination of the photographs obtained disclosed peculiar features. It was at once evident that the spectrum of the east limb was nearly always less well defined than the spectrum of the west limb over a considerable region of the spectrum near the cyanogen bands. The photographs dealt with may be divided into two classes: firstly, about 35 "adjustment photographs" taken for finding the best adjustment of the instrument and for testing the effects of some exaggerated maladjustments; and secondly, about 10 "rotation photographs," each exhibiting two spectra of the east limb alternating with two spectra of the west limb, all taken with approved adjustment of the instrument.

A great deal of care and time have been devoted to the critical study of the evidence; and though at first I was led to suspect that, in spite of great care in adjusting the instrument, and in making sure that the optical beam was arranged exactly similarly both for east limb and for west limb, some unexpected error had crept in, I am now convinced that the right interpretation of the peculiar effects lies in accepting them as real, and not instrumental.

The spectrum of the east limb was in nearly every case less clearly defined than that of the west limb. Now, in a malfocussed photograph, one can, from the appearance presented by a single isolated line, predict with considerable certainty what the appearance of various groups of lines will be. But the appearances presented by the spectra of the east limb do not agree with prediction based on study of isolated lines or edges. In particular, the cyanogen band itself at the east limb shows in general a double edge, as if

two similar bands are superposed, with slight relative displacements which vary from day to day. The cyanogen band at the west limb shows in general a single slightly intensified edge, as if there might be two bands superposed, with such slight displacement as not to be measurable. There are many other minute differences between corresponding lines in the spectra of the east and west limbs.

Three of the "rotation photographs" were picked out as showing the best definition: namely

L. 32 1907 Sept. 15, 10.23 a.m. G.M.T (civil).

L. 41 " " 11.54 " "

L. 42 " " 12.20 " "

These have been measured by my assistant, W. H. Manning, under my direction. Six iron lines, two chromium lines, and five cyanogen lines were chosen for measurement between wave-lengths 3871 and 3898. Each plate was measured twice in reversed positions on the Zeiss Comparator. The values of the displacements (δR), East-West, are given for each line in the following table; the values are expressed in millimetres. Four of the five cyanogen lines are really close double pairs, which were bisected as single lines. They are indicated in the table.

Wave-length.	Origin.	L. 32.	L. 41.	L. 42.	Mean.	
3871.963 ?	Fe	0.0330	0.0344	0.0304	0.0326	Fe
73.065	CN	347	297	397	347	CN
73.903	Fe	336	316	312	321	Fe
76.815	Fe	363	342	355	353	Fe
82. $\left\{ \begin{smallmatrix} 224 \\ 309 \end{smallmatrix} \right\}$	CN	329	317	334	327	CN
82. $\left\{ \begin{smallmatrix} 439 \\ 530 \end{smallmatrix} \right\}$	CN	322	368	359	349	CN
82. $\left\{ \begin{smallmatrix} 650 \\ 733 \end{smallmatrix} \right\}$	CN	275	345	280	300	CN
82. $\left\{ \begin{smallmatrix} 828 \\ 893 \end{smallmatrix} \right\}$	CN	287	344	284	305	CN
83.778	Cr	255	267	301	274	Cr
85.657	Fe	299	326	306	310	Fe
86.942	Cr	323	338	342	334	Cr
90.986	Fe	321	343	330	331	Fe
3897.596	Fe	301	321	337	320	Fe
Mean					0.0323	

It will be seen that

6 iron	lines give a mean displacement, E.-W.,	mm. 0.0327
2 chromium	" " "	0.0304
5 cyanogen	" " "	0.0326

It thus appears that the cyanogen lines give displacements (and consequently also a solar rotation-period) sensibly the same as those given by iron lines of solar origin. These displacements of lines relate to spectra taken from solar light gathered at the east and west ends of the solar equator, within about 5° of solar latitude from the equator, at points situated within the limb by about $\frac{1}{20}$ of the radius of the Sun's apparent disc. I do not put them forward as satisfactory determinations of the equatorial velocity of the Sun.

To deduce the velocities corresponding to the displacements, we must use a factor, $L/\lambda \cdot d\lambda/dR$, which works out to be sensibly 100. For the velocity per tenthmetre (L/λ) is

77.49 km/sec at wave-length 3872

and 76.96 " " 3898

whilst the linear dispersion is such that $d\lambda/dR$ is equal to

1.297 tenthmetres per millimetre at 3872,

and to 1.299 " " 3898.

Thus the factor ranges from 100.6 to 99.8, and for our present purposes we may take its value as 100 over the range of spectrum measured.

Hence the displacements expressed as velocities are

for the 6 iron lines, 3.27 km/sec

2 chromium " 3.04

5 cyanogen " 3.26.

The corresponding equatorial velocities are got by halving these numbers. It is seen that the uncorrected numbers are a little lower than Dunér's and Halm's.

The main point, however, is that for these three determinations cyanogen is shown to be in the solar atmosphere in the same sense that iron and chromium are.

The wave-lengths of the cyanogen lines used in this determination have been also deduced with reference to three iron lines as standards. They are found to differ from Rowland's values by less than one hundredth of a tenthmetre, as will be seen from the accompanying table.

Wave-length (Rowland).	Adjustment Plate L. 20.	Rotation Plates.			Mean.	Origin.
		L. 32.	L. 41.	L. 42.		
3871.963 ?	3871.887	.881	.887	.881	.884	?
73.073	73.072	.069	.073	.069	.071	CN
73.903	Standard	...	...	...	(.903)	Fe
76.815	76.813	.805	.812	.813	.811	Fe
82. { $\begin{smallmatrix} 224 \\ 309 \end{smallmatrix}$ } (266)	82.272	.266	.271	.274	.271	CN
82. { $\begin{smallmatrix} 439 \\ 530 \end{smallmatrix}$ } (485)	82.483	.472	.479	.483	.479	CN

Wave-length (Rowland).	Adjustment Plate L. 20.	Rotation Plates.			Mean.	Origin.
		L. 32.	L. 41.	L. 42.		
82. { $\begin{smallmatrix} 650 \\ 733 \end{smallmatrix}$ } (691)	82.682	.673	.677	.679	.678	CN
82. { $\begin{smallmatrix} 828 \\ 893 \end{smallmatrix}$ } (860)	82.856	.850	.856	.853	.854	CN
83.778*	83.782	.774	.774	.772	.775	Cr
85.657	Standard	...	...	...	(.657)	Fe
86.942	86.945	.949	.949	.951	.948	Cr
90.986	90.989	.984	.983	.988	.986	Fe
97.596	Standard	...	...	...	(.596)	Fe

The apparent duplication of the edge or head of the CN band is, as has already been stated, more marked at the east limb than at the west. It is much more difficult to measure the displacement of edges than the displacement of lines in the band. Nevertheless I have made some measurements of the displacement; and if these are interpreted as indicating a Doppler effect, the results may be summarised as follows, the velocity of the east limb always being towards Earth.

Plate.	Date.	East Limb.		West Limb.	
	1907.	h m			
L. 6	Aug. 17,	5.27 p.m.	} Spectra similar. No measurable displacement of edges.		
L. 8	Sept. 6,	10.50 a.m.		Velocity 16 km/sec	Displacement very small.
L. 10	Sept. 8,	10 "	"	14 km/sec	" "
L. 14	"	3.55 p.m.	"	12 km/sec	" "
L. 32	Sept. 15,	10.23 a.m.	"	? 4 km/sec	" "
L. 41	"	11.54 "	"	? 5 km/sec	" "
L. 42	"	12.20 p.m.	"	? 5 km/sec	" "

This progressive change of the duplication of the edge is seen to go on for 9 days, and so can hardly be connected with ordinary disturbances of a local nature on the Sun's surface. The cyanogen involved cannot be far from the Sun, for otherwise it would be detected in the spectra of both limbs. It is seen that nothing of the order of cometary velocities is as yet detected.

I have spent some time in considering the possible influence of Daniel's comet which reached perihelion on September 4, with a velocity of 58 km/sec at a distance 0.512; the Earth passed closest to the path of the comet on September 12, as was pointed out by Kritzinger (*Ast. Nach.*, 4198). The comet itself had passed the point on July 27. But in the solar spectrum no sign has been detected that can fairly be attributed to the presence of the comet near the Sun.

Much more evidence is required before the case can be completely elucidated, and this note must be regarded as of a preliminary nature.

The Ultra-Violet Region in Sun-spot Spectra.

By John Evershed.

It is well known that the more conspicuous of the lines which are intensified or otherwise affected in the spectra of sun-spots are found in the less refrangible region of the spectrum, those in the red being by far the most easily seen, whilst in the ultra-violet the lines of the same elements, although far more numerous in this region, seem to be totally unaffected.

A considerable number of photographs of sun-spot spectra, taken in the ordinary way, in the region more refrangible than G, have from time to time been examined in detail by the writer, but, excepting always the hydrogen lines and H and K, these have always shown an entire absence of details which could be certainly distinguished from the adjacent photosphere spectrum.

Recently, however, with improved apparatus and exceptionally favourable atmospheric conditions, a series of spectra have been obtained at this observatory showing a considerable number of affected lines in the region λ 3990-4350.

Owing to the intrinsic darkness of the spot band in the ultra-violet, a very long exposure is necessary, in photographing the umbral spectrum, to give a density equal to that of the spectrum of the surrounding photosphere. Thus I have found for the region near K the umbra requires from ten to twelve times the exposure needed for the photosphere, and it is obvious that in long exposures the diffuse light from the sky will impress the plate more or less, superposing the general solar spectrum on the true spot spectrum. It is questionable, however, whether this admixture of skylight is sufficient to explain the apparent poverty of detail in the ultra-violet, as compared with the red and yellow regions of the spot spectrum.

The photographs were taken in the fourth order of a Rowland plane grating, having 14,438 lines to the inch and a ruled surface of 3 inches. The collimator used is a visually corrected lens of $2\frac{1}{2}$ inches aperture and 36 inches focus. The camera lens is a plano-convex of 4-in. aperture and 7-ft. focus for H. The slit is provided with a sliding shutter, having a <-shaped aperture, which enables its length to be varied within wide limits during an exposure. In photographing a spot spectrum, the slit is reduced to a length equal to about two-thirds or less of the diameter of the umbral image. A long exposure is then given, after which the slit is lengthened, and the exposure continued for a short interval to impress the adjacent photosphere spectrum.

The spectrograph was erected in the spectroheliograph room, using as image lens the 12-in. photo-visual lens usually employed for the spectroheliograph. The exposures given on spot and photosphere were as follows:—

Plate exposed 1907 June 20. λ 3900-4140.

No.	Umbra.	Photosphere and Umbra.	Total Exposure.
1	120 seconds	15 seconds	135 seconds
2	180 "	25 "	205 "
3	205 "	20 "	225 "

Plate exposed, 1907 July 16. λ 4090-4350.

1	20 seconds	7 seconds	27 seconds
2	30 "	5 "	35 "
3	40 "	5 "	45 "

The first set of three exposures represents the spectrum of the large southern spot, which passed the central meridian on June 21. The second series represents the same spot after a rotation of the Sun. The latter was not obtained under nearly as favourable conditions as the former, and probably many more affected lines will be added to the list in subsequent photographs.

The two plates were examined and measured quite independently; and in the region where they overlap, the agreement in the estimates of intensity was remarkably good, although, as was to be expected, fewer affected lines were noted on the July plate.

In the following table I give only those lines in the spot spectrum which can be quite certainly distinguished from the photosphere spectrum by an increase or decrease of intensity, or by the absence of a line in the one spectrum which is present in the other. Since a considerable number of the lines visible in the umbral spectrum could not be traced on the photosphere spectrum, the positions of these were measured with a micrometer with respect to neighbouring known lines, from which the wave-lengths were deduced. The measured wave-lengths are given in the first two columns to two places of decimals only, to distinguish them from those lines which could be identified with solar lines by inspection: to these Rowland's values of the wave-lengths are given. The third and fourth columns give the estimated intensities in photosphere and umbra respectively, the former being from Rowland's table. In estimating intensities the spot line is compared with one or more of the neighbouring solar lines having the same apparent intensity, and the intensities of these comparison lines are taken from Rowland's table after comparison with Higgs' map.

It is to be noted that, as in the visible region of the spectrum, titanium and vanadium figure largely among the strengthened lines, whilst of the seven affected iron lines six are weakened in the spot. The hydrogen lines γ and δ are notably weakened, both in width and intensity. Both are displaced relatively to the photosphere lines, but, curiously enough, in opposite directions, γ .05 towards the red on the July plate, δ the same amount towards the violet on both plates.

List of Lines affected in Sun-spot Spectra in the region between H ζ and H γ .

Plate Exposed June 20.	Plate Exposed July 16.	Intensity in Photo- sphere.	Intensity in Umbra.	Element.	Remarks.
λ	λ				
3911'316	...	0	3	Nd	
3914'87	...	0 n	1	Fe	The solar line is at 3194'880.
3930'022	...	2	3	Ti	
3933'825 K	...	...	...	Ca	Narrow bright line. Not displaced with respect to the chromosphere absorption line K3.
3960'422	...	4	3	Fe	
3964'663	...	3	<2	Fe	
3996'752	...	00	2	...	
3968'625 H	...	...	...	Ca	Narrow bright line. Not displaced with respect to the chromosphere absorption line H3.
4015'532	...	0	1	...	
4017'925	..	0	1	Ti	
4019'450	...	0	1	Co	
4023'834	...	2	4	Sc	
4047'93	...	...	2	...	Absent in photosphere.
4048'224	...	1 n	...	...	Absent in umbra.
4050'830	...	2	1	Fe	
4054'69	...	...	3	...	The solar line at 4054'591 is distinctly more refrangible and gives the umbral line a shading on the violet side.
4064'36	...	1	2	Ti	
4095'423	...	0	...	Mn	Absent in spot.
4095'633	4095'633	0	2	V	
4097'61	...	000	0	...	
4098'335	...	5	4	Fe	
4099'327	...	00	2	Ti	Probably the line at 4099'207, intensity 0, is included.
4101'921	...	2	1	Fe	
4101'85 H δ	4101'85	40	10	H	Much reduced in intensity in umbra and displaced to violet '05 A.U. in both spectra.
4102'31	4102'31	0	2	V	
4102'52	4102'55	...	0	...	Probably this is the yttrium line at 4102'541, intensity 0.
4102'71	...	...	00	...	
4105'318	4105'318	2	5	= V	
4105'98	4105'92	000	0	...	
...	4111'154	1	00	Mn?	Almost obliterated.

List of Lines affected in Sun-spot Spectra, etc.—continued.

Plate Exposed June 20.	Plate Exposed July 16.	Intensity in Photo- sphere.	Intensity in Umbra.	Element.	Remarks.
λ	λ				
4112'869	...	1	3	Ti	
4113'68	4113'69	000 n	1	...	Probably a double line.
4114'28	4114'18	00	2	...	
4117'113	...	0	...	...	Absent in umbra.
4117'63	4117'71	...	0	...	
4120'74	4120'74	...	1	...	Distinctly less refrangible than the solar line at 4120'775.
4123'664	...	1	5	Mn	{ The intensities of these two lines seem exactly reversed in the umbra.
4123'907	...	5	1	Fe	
4125'52	...	000	3	...	
4128'46	...	00	2	...	
4128'894	4128'894	2	...	...	Absent in umbra.
4129'10	...	...	2	...	Absent in photosphere.
4131'50	4131'507	0	1	Cr	
4133'60	...	...	0	...	Absent in photosphere.
4135'915	...	0	1	Zr	
4139'60	...	...	3	...	Probably a double line. Absent in photosphere.
Spectrum ends at 4140	4140'910	00	0	...	
	4146'78	0	2	...	
	4153'20	00	1	Cr	
	4159'805	0	1	Ti	
	4163'18	...	1	...	
	4252'468	0	> 1	Co	
	4262'086	2	1	...	
	4262'142	...	...	...	
	4281'530	0	2	Ti	
	4299'803	2	3	Ti	
	4300'732	3	4	Ti	Rowland gives intensity 2, which seems too small.
	4340'31	0	1	Cr?	
	4340'68	20	10	H	The line is about '60 wide in sun, and '35 in spot, where it is displaced towards red, '05 unit.
	4341'167	0	2	V	
	Spectrum ends at 4350				

The Spectrum of Comet 1907 d (Daniel). By John Evershed.

Notwithstanding the very unfavourable conditions prevailing here during the south-west monsoon, attempts were made to photograph the spectrum of this comet on several occasions in August and September. Owing to the short intervals of time practically available for making exposures on the comet (three-quarters of an hour at most), it seemed necessary to use a spectrograph having the greatest possible light-efficiency. I therefore determined to try whether an objective prism spectrograph of short focal length could be successfully employed. On account of the almost constant presence of cloud, more or less thick, in the eastern sky, the results do not come up to expectation, but are perhaps of sufficient interest to place on record.

A prismatic camera was constructed with the two very perfect 60° prisms, of specially selected crown glass, which were successfully used at recent eclipses. The prisms have an effective aperture of 42 mm., and the photographically corrected lens has a focal length of about 600 mm. The instrument was attached to the 6-in. Cooke equatorial in the south dome of this observatory, the plane of dispersion being made parallel to a circle of declination. For guiding, a straight-edged bar was placed in the eyepiece of the finder attached to the equatorial, and this was made parallel to the diurnal motion. In making an exposure, the comet's nucleus was kept on the edge of the bar, and nearly in the centre of the field (defined by a cross-wire), by means of the slow-motion handles of the equatorial.

In the course of several weeks, about the time of the comet's maximum brightness, only three fairly favourable opportunities occurred. These were August 28, September 3, and September 15. The best result was obtained on the first-named date, with an exposure of half an hour. On September 3 the comet was obscured by cloud for about half the available time before daylight, and during this interval the opportunity was taken to photograph the spectrum of Procyon on the same plate, the star being brought to the edge of the bar in the eyepiece, but at a little distance from the centre of the field. In the plate exposed for twenty minutes on September 15, under apparently favourable conditions, no trace of the spectrum can be seen. This is probably due to the low altitude of the comet, for the spectrum of Regulus, then about 3° N. of the comet, is only faintly impressed on the plate. Wratten's "Drop Shutter" plates were used in all the trials.

In the spectrum of August 28 the most striking features shown are a pair of extremely bright lines in the ultra-violet, corresponding with the nucleus of the comet,* and a series of monochromatic images of the tail, having the following approximate wave-lengths:—

$$\lambda \text{ 358, 369, 378, 401, 426, 455.}$$

* Owing to a slight drift of the comet in R.A., the images of the nucleus are linear.

These radiations are not specially bright in the comet's nucleus, but they extend from 5° to 15° into the tail, whilst the above-mentioned bright lines seem to be confined to the region of the nucleus. Altogether 12 lines or groups of lines have been measured on this plate, and the wave-lengths determined graphically, using the 12 hydrogen lines from $H\beta$ to $H\nu$ inclusive in the spectrum of Procyon and of Sirius to obtain the dispersion curve. In the spectrum of September 3, with Procyon photographed on the same plate, the pair of bright lines in the ultra-violet are seen to be a little more refrangible than $H\zeta$ (λ 3889); and as their distance apart corresponds with about 11 units in wave-length, there can be no hesitation in ascribing them to the cyanogen lines at λ 3871.5 and λ 3883.5. In this plate, however, the images are too faint for measurement.

In the table which follows are summarised the results of measures of the spectrum of August 28. As most of the spectral images on this plate are broad and ill-defined, I give in the second column the approximate limits of wave-length of each line or band; and in the third column the mean wave-length, or the positions of maximum brightness. In the fourth column is entered the length of tail in degrees which can be traced in each radiation. I can assign no origin for the radiations, which seem characteristic of the tail, except the band at λ 455, which, according to Campbell, may probably be due to cyanogen.* The continuous spectrum, which is faint throughout, ends at about λ 490.

No.	Limits of λ .	Mean λ .	Length of Tail in Degrees.	Probable Identification.	Remarks.
1	357 } 359 }	358 $\pm$...	3 $\pm$...	Cyanogen?	Exceedingly faint images of tail.
2	367 } 370 }	369 $\pm$...	4 $\pm$...	...	
3	377 } 380 }	378 $\pm$...	5 $\pm$...	...	
4	3863 }	3873	...	Cyanogen.	
5	3885 }	3884	2	Cyanogen.	Very intense lines : 3884 the strongest in the whole spectrum.
6	3995 } 4034 }	4015 ...	1.6 ...	...	
7		4129 $\pm$...		...	Extremely faint traces of tail. Campbell gives a faint line at 4126 in comet b of 1893.
8	4190 } 4221 }	4200 4215		Cyanogen. Cyanogen.	No tail. Traces of lines at these positions.

* *Pub. Ast. Soc. Pacific*, vol. v. p. 209.

No.	Limits of λ .	Mean λ .	Length of Tail in Degrees.	Probable Identification.	Remarks.
9	4239 } 4282 }	4260 ...	1'4 ...		A very faint line is given by Campbell at λ 426 in comet <i>b</i> of 1893.
10	...	4360	...	...	Faint bright spot in continuous spectrum. A bright line is given by Campbell at λ 4366 in comet <i>b</i> of 1893.
11	4523 } 4584 }	4553 ...	1'1 ...	Cyanogen ? ...	Campbell gives a band near λ 455 in comet <i>c</i> of 1893.
12	4650 } 4736 }	4682 ...	'4 ...	Blue band of carbon.	Max. brightness esti- mated at λ 4682.

Kodaikanal Observatory.

Note on the Ancient Solar Eclipses discussed by Mr. Cowell.
By A. C. D. Crommelin.

The results derived from these eclipses by Mr. Cowell are so important and far-reaching that it is desirable to remove all uncertainty as to possible errors, especially in view of the fact that Mr. Nevill published some results purporting to be deduced from the same formula, but inconsistent with those given by Mr. Cowell himself; I accordingly undertook an independent calculation of the six eclipses - 1062, - 762, - 602, - 584, - 430 and + 197, which are the most important and best authenticated ones. I obtain results practically identical with Mr. Cowell, the discordance in no case exceeding 2", which is an absolutely negligible quantity.

Several smaller terms in latitude were then introduced, which had some slight effect on the residuals, but not enough to affect the argument in any way; they possibly produce a small diminution in the relative acceleration of the Sun and the node, but only to the extent of $\frac{1}{2}''$ or less.

Two points suggest themselves as worthy of mention regarding the eclipse of - 1062; viz.—(1) Mr. King's recently published book gives a translation of the inscription in which it occurs, which is a record of omens occurring in the city of Babylon (wild beasts entering the streets, dogs entering the temples, etc.); hence there

can be no reasonable doubt that the extinction of the Sun, recorded as an omen, was likewise witnessed from Babylon itself.

(2) The date of the phenomenon is given as Sivan 26 ; now, as the months began with the first observation of the Moon, the 26th of the month must be within a day or two of new moon ; this decidedly increases the probability that the recorded solar darkening arose from an eclipse.

Both Professor Newcomb and Mr. Nevill have rejected the suggested explanation of the apparent acceleration of the Sun as arising from a diminution of the Earth's rate of rotation. The point, however, is such a simple one that it seems worth while to restate it in other words, in the hope that they may more definitely indicate their reasons for dissenting from it.

(1) A slowing of the Earth's rotation from tidal friction necessarily involves an increase in the Moon's distance, in order that the moment of momentum of the Earth-Moon system may be conserved.

(2) A rough calculation was given showing that the lengthening of the Moon's period arising from this may be nearly as great as the apparent shortening due to the increase in the length of the day.

(3) In the case of the Sun's period, the shortening due to the latter cause would act unimpeded, so that an apparent acceleration of the Sun comparable with that of the Moon would result.

Note on the Permanency of some Photo-visual Lenses.

By William J. S. Lockyer, M.A., Ph.D. (Plates 1, 2, 3.)

The Solar Physics Observatory at South Kensington is in possession of numerous photo-visual lenses which are employed in several instruments in frequent use. All these objectives have in time developed curious markings on one or more of their internal surfaces. The object of the present note is to draw attention to, and to give a brief description of these markings.

Each of the lenses in question consists of a combination of three elements, the front and back lenses being double convex and the middle double concave. The front and middle lenses are nearly in contact, but a small air-space separates the middle from the back lens.

The material with which the lenses are made is as follows :—

The front lens is made of Schott's baryta light flint glass (O 543), the negative or middle lens is of Schott's boro-silicate flint glass (a variety of their O 164), while the third is made of a light silicate crown (Schott's O 374).

The lenses to which reference will be made vary in aperture from 3 to 12 inches, and have been left, as regards their inner surfaces, untouched in their respective instruments for periods varying from 23 to 83 months.

Aperture in Inches.	Date of Mounting.	Date of Dismounting.	Interval in Months.	Notes on Markings.	Conditions of Situation.
12.	March 12, 1905.	Feb. 18, 1907.	23.	Very fine curly markings closely packed.	In good airy room, tem- perature variable.
4.	March 16, 1904.	Feb. 21, 1907.	35.	These lenses look quite clear, but on close exami- nation it is found that there is a distinct indica- tion of the beginning of the markings in the form of minute streaks.	In a room well heated throughout the year.
4.	March 16, 1904.	Feb. 21, 1907.	35.		
3.5.	October 1903.	Feb. 21, 1907.	40.	Beautiful feather-like markings, fairly evenly dis- tributed, but denser near centre.	Well aired room, tem- perature variable.
3.	January 1900.	Dec. 14 1906.	83.	Markings all over the lens, but smaller and more closely packed towards centre.	Subjected, possibly, to vapours from arc in labora- tory. Room always well warmed.
3.	January 1900.	Dec. 14, 1906.	83.	Well separated curly markings, more numerous near centre.	

The preceding table contains a summary in convenient form indicating the intervals between the times of mounting and dismounting the objectives, the conditions of their situation, and brief notes on the markings developed.

In order, in the first instance, to indicate the appearance of the markings in question, the following four selected photographs will serve as examples. It may, however, be first mentioned how these photographs were secured.

The whole combination was first removed from the instrument in which it is employed and placed in a V-shaped wooden stand in front of a window. The camera was placed about 2 feet away from the lens and about 3 feet from the window, when the markings were carefully focussed on the ground-glass. The system of illumination of the lens under examination was as follows. The space between the lens and the camera was first covered in with black velvet. About a foot away from the lens, but on the opposite side of it to the camera, a large dull black piece of cardboard was placed near the window in nearly a vertical position to serve as a black background. The lens itself was illuminated by daylight passing through the window and falling obliquely on the back portion of the combination. Unfortunately it was found very difficult to eliminate the reflections of the window from appearing on the lens, but they are not sufficient to detract from the main object for which the photographs were taken. The photographs show, therefore, the peculiar markings on one or more of the inner surfaces of the lenses, as white on a dark background.

Fig. 1 (Plate 1) represents the 3-in. objective which has been employed in an instrument for 83 months. The markings, it will be noticed, are small, and near the middle give the lens a distinct mottled appearance. Nearer the edges their structure becomes more pronounced, and there is a greater distance between them.

Fig. 2 (Plate 1) represents the markings on another 3-in. lens which forms the camera objective of the same instrument. This lens was mounted and dismounted at exactly the same time as that shown in fig. 1 (Plate 1), and during this interval of 83 months it was situated within a foot of the other lens.

The different structure and number of the markings is very striking, and can be judged best by closely examining the photographs.

In fig. 1 (Plate 2) we have another example of quite a different appearance. This lens has an aperture of 3.5 inches, and has been in use as an objective to a small telescope for 40 months. The markings in this case are of a much finer type than those previously mentioned, and are far more elaborate in their structure.

This lens exhibits, in addition, a second set of markings, which appears on another of the interior surfaces of the combination, but which could not be photographed under the same illumination and distance, and therefore cannot be seen in fig. 1 (Plate 2). By

reversing the combination in the V-shaped mount, refocussing the camera and varying the direction of the daylight illumination, a very successful negative was secured, a reproduction of a positive from which is seen in fig. 2 (Plate 2). Around the centre of the lens will be observed a great number of small white spots which represent the markings in question. These are quite different in form and character from any of those which have been previously described.

In the case of two 4-in. lenses a recent examination has shown that after an interval of 35 months they are just beginning to show signs of development of markings.

In this initial stage one has observed, with the help of a watchmaker's glass only, that the markings take the form of very small single streaks, more or less homogeneously scattered over the whole lens, but a little more sparse nearer the edges than about the centre.

The large 12-in. objective has developed those markings at a much greater rate. After an interval of only 23 months very fine markings, of simple structure, but fairly closely packed together, extend over the whole surface of the lens, and, as before, their structure becomes more complex as the edge of the lens is approached.

So far, no mention has been made as to the particular surface of the combination on which the markings are to be found. As a matter of fact, although it is quite simple to take to pieces any of the lenses which have been examined, it is not easy to replace them properly centred in their cells. For this reason, therefore, only one of the above-mentioned lenses has been thoroughly examined by separating the component lenses forming the combination. The particular objective thus treated was that of 3.5 inches aperture, and it exhibited both kinds of markings to a very great degree.

When markings were first noticed to develop on one of the inside surfaces of the combination it was thought that they might be due to the possible lack of permanency of the boro-silicate flint glass, since there seemed more doubt connected with the permanency of this material* than with those used for the other lenses. It was therefore found, with some surprise, that when the 3.5-in. objective was taken to pieces, both surfaces of the negative lens were perfectly clean and unmarked, and therefore not deteriorated in any respect. This result was highly satisfactory from the point of view of the lasting power of the boro-silicate flint glass, and showed that, as mounted between the two other lenses, 40 months' use had not affected it. It was the inner surface of the back lens, of light silicate crown glass, which was affected to the greatest extent, and on which the markings illustrated in the above figures were scattered. This surface, it will be remembered, is separated from the back surface of the negative lens by a small air-space. It may be mentioned that no balsam or like

* Especially where sulphuretted hydrogen or sulphuric acid abounds, as in a town atmosphere.

material is employed in this combination to cement the lenses together, but the surfaces are kept separate by thin washers.

In order to investigate more thoroughly the nature of the two different kinds of markings, namely, those which appeared on the inner surfaces of the back and front lenses of the 3·5-in. objective, the combination was taken to pieces and the markings microscopically examined.

This inquiry was facilitated by the kindness of Professor J. B. Farmer, D.Sc., F.R.S., of the Royal College of Science, who not only allowed me to use one of his microscopes in his own room, but also examined the markings with me. It was at once obvious that we were not here dealing with any form of vegetable growth, as seemed at first probable by the general appearance of the markings, but that both kinds were of a crystalline nature.

In the case of the back lens the crystallisation seemed to have taken place on the surface of the lens, and had the appearance of a deposit on the surface. Each fungus-like figure seemed to have originated from a small area, not a single point, and developed radially in numerous directions, throwing out ramifications as the growth from this area progressed. Under the microscope it was found that the markings were really crystals, forming at first about the small area, and then gradually growing outwards, crystal by crystal, until they formed chains of crystals, giving the fungus-like growth described above. There seemed little doubt that if this process were allowed to continue, the individual groups of crystals would all eventually unite, and seriously interfere with the transparency of the combination. In the lens under examination several of these groups have already become interlaced and instances of this can be seen in the centre portion of the lens illustrated in fig. 1 (Plate 2).

In the case of the markings on the back surface of the front lens, the form of crystallisation is quite different. Here, under the microscope, the markings (seen in fig. 2, Plate 2, as white dots scattered about the centre of the lens) are composed each of a little irregular group of crystals, formed one above the other, and projecting from the surface of the lens, not embedded in it. There is little appearance of lateral growth to the extent described in the case of the markings on the back lens. Scattered over the surface of this lens are also small single crystals, which suggest the first stage in the building up of these heaps. In this case also it is probable that if this process of crystallisation were allowed to continue, more single crystals would be formed, the single ones already existing would each develop into a small pile of crystals, and the lens would gradually become less transparent.

By the kindness of Mr. W. H. Merrett, A.R.S.M., the Instructor in Assaying in the Royal College of Science, I was permitted the use of the photomicroscope set up in the metallurgical laboratory of that institution. With the help of this instrument and with his assistance I was able to take large scale photographs of the

crystalline formations on each of the two lenses, and some of these are reproduced on Plate 3.

Figs. 1, 2, 3 show three of the individual small groups of crystals formed on the back surface of the front lens, to which reference has just been made. The magnification employed for these photographs was 700. It will be seen that the formation is quite irregular, and, as a rule, there does not seem to be a point of origin, as if their existence was due in the first instance to the presence of a speck of dust. On the surface of this lens there appear also single crystals which are totally different from those just described. They do not show the lateral growth, as is here illustrated in figs. 1, 2, 3, but they are very much more raised from the surface on which they are formed.

The markings on the inner surface of the back lens of the combination are illustrated in figs. 4, 5, and 6 of Plate 3. Fig. 4 gives a general idea of the middle portion of one of the groups under a magnification of 45 diameters. It will be noticed that there does not seem to be a distinct single point of origin, but that the group seems to spring from a small area. An interesting point to which attention may be called is the fact that none of the lines of crystals cross each other: this can be observed in several instances in fig. 4 (Plate 3) where these lines approach each other. Further, the extremity of each line, where the crystallisation can proceed unhindered, is nearly always capped by a complete crystal.

Fig. 5 (Plate 3) is a more highly magnified (150 diameters) portion of fig. 4, and for identification purposes similar portions in figs. 4 and 5 have been lettered A, B, C. In this figure the building up of the lines by successive deposits of crystals can be more clearly seen.

Fig. 6 (Plate 3) is a portion of another group altogether. The magnification here is 700 diameters. It shows perhaps more clearly not only the individual crystals which help to build up the lines which compose the groupings previously mentioned, but the complete form of the last crystal deposited at their extremities.

Attention may here be drawn to the mottled appearance which can be seen in fig. 4 (Plate 3) in those parts of the lens where the crystals have not been formed. These markings, or "globules," as they are termed, evidently represent the stage previous to the actual crystal formation, and must have covered the whole surface of the lens before the crystals themselves were developed. As crystallisation set in they disappeared in the neighbourhood of each crystal, as if the crystals themselves required this material for their formation. The existence and behaviour of these globules are well known in crystallography, as I have since been informed by Professor J. W. Judd, of the Royal College of Science, South Kensington. The whole phenomenon is clearly described and illustrated by Professor O. Lehmann in his magnificent work entitled *Flüssige Kristalle* (Wilhelm Engelmann, Leipzig, 1904). In this connection Professor Lehmann writes (p. 112), "Das die Globuliten in der Nähe von

Kristallen verschwinden, so dass um diese ein Hof entsteht, erklärt sich vor allen dadurch, dass überkühlte Schmelzen leichter löslich sind als die kristallinisch erstarrte Substanz, in einzelnen Fällen auch durch Strömungen, welche theils durch Dichte-Differenzen, theils, speziell bei Präparaten ohne Deckglas, durch die Oberflächenspannung veranlasst werden."

Although the microphotographs reproduced with this paper indicate in a general way the structure and crystalline nature of the markings, some difficulty was met with in attempting to secure satisfactory photographs with high powers, that is, with magnifications of 150 diameters or more.

The *thickness* of the crystals and their deposition on a *curved surface* rendered it impossible to focus the objects in their entirety in a satisfactory manner, so that one had to be contented with the somewhat blurred images when these magnifications were employed.

In order to test whether the markings on the two surfaces of the objective were responsible for any absorption of light passing through the combination, the objective was set up on the V-stand mentioned previously and photographed. On this occasion the background used was white instead of black, and light was only allowed to enter the lens by reflections from this surface. If the markings absorbed light, it was expected that the resulting photograph should give one the picture of the lens with the markings dark instead of light, as was shown in the previous illustrations (Plates 1 and 2). This is exactly what occurred, and both sets of markings were faithfully recorded. Those on the back lens, which covered the larger area, were not, fortunately however, so opaque as those on the front lens, but still a considerable absorption of light was indicated, a quantity quite sufficient to detract from the efficiency of the combination.

Inquiry was next made into the probable causes of the deposition of the crystals. The weathering of glass surfaces, on account of the dust, water-vapour, etc. in our atmosphere, has received considerable attention in Germany, and quite a mass of literature now exists on the subject. A very convenient summary of such investigations will be found in Dr. H. Hovestadt's book on *Jena glass, and its scientific and industrial applications*, an English edition of which appeared in 1902 (Macmillan & Co.).

In chapter x. of this volume the chemical behaviour of glass surfaces is dealt with, and attention is chiefly confined to glasses which are most closely related to the work of the Jena glass-making laboratory. Since the photo-visual lenses here discussed are made from material supplied from Jena, the information given is therefore specially serviceable on the present occasion. There seems little doubt that it is chiefly the moisture in the atmosphere, and not dust particles, which is responsible for the actions which occur on the surfaces of the lenses here described, for the surfaces attacked are all inside, and although protected to a great extent from dust, they are still liable possibly to action by water-vapour.

It has been shown that the durability of glass depends chiefly on its power of resisting attack by water. Glass being hygroscopic, absorbs moisture to a varying degree, and this moisture enters into chemical combination with its surface. As a result of this absorption, the alkaline components of the glass are gradually set free, and an opportunity is at once afforded for the carbonic acid of the air to combine with the alkalies and form carbonates, which are deposited in the form of crystals.

Dr. E. Zschimmer* made in 1901 an analysis of about 200 pieces of glass with polished plane surfaces, which had been stored, with a view of subsequent testing, in a dry place in Jena for several years, but so protected that they were only imperfectly excluded from air. He found that the behaviour of silicates without lead depended almost entirely on the amount of alkali contained in them. If the amount was as small as 10 per cent., dust particles initiated a deposit which he termed "dusty disintegration"; over 10 per cent., a "homogeneous decomposition" set in which attacked the glass uniformly. When the amount of alkali reached 20 per cent. the deposit became visible to the naked eye, and the greater the proportion of alkali, the coarser the phenomena, *i.e.* the formation of drops and the crystallisation of carbonates. The action of deliquescent carbonate of potash is to cover the surface with more or less minute drops, while carbonate of soda, being only slightly hygroscopic, covers it with assemblages of crystals.

In the case of the lenses dealt with in this paper, the formation of the single crystals took place on the baryta light flint glass, while the assemblages of crystals occurred on the light silicate crown.

In order to find out the actual composition of the latter glass, Messrs. Schott and Genossen of Jena were communicated with, and asked whether they would be good enough to supply this information. Needless to say, the requisite data were soon forthcoming, and I should like to take this opportunity of expressing to them my best thanks for so willingly sending me the facts desired. The following is an abstract of their reply, dated 12th April 1907, which they have kindly allowed me to publish:—

"We beg to say that the glass in question of our type O 374 constitutes a crown glass holding a high percentage of alkali, we had made at some previous time, of a similar composition as French glass. Owing, however, to its being wanting in permanency, we discontinued later on the manufacture, and hence this glass does not appear on our present catalogue.

"Its chemical composition is the following:—

B_2O_3 3%, K_2O 17%, Na_2O 5%, CaO 3·8%, PbO 1%,
 As_2O_3 0·4%, SiO_2 69·8%."

With these facts before us, one is led to conclude that the

* *Chemiker Zeitung*, 1901, 25, No. 69.

excess of the alkali has acted in the way suggested by Dr. Zschimmer, and produced the assemblages of crystals described above.

It may be here remarked that these assemblages of crystals are very similar in growth to those formed by the crystallisation of potassium permanganate, as described and illustrated by Professor Lehmann on page 124 of the volume on *Flüssige Kristalle* to which reference has previously been made.

In order to try and reproduce the forms of crystallisation deposited on the lenses, a series of experiments was made with partial success.

As potassium (17%) was the chief ingredient next to silicon (69·8%) in the composition of the glass, solutions of pure potash with distilled water were made and poured on to the cleaned surfaces of several cover-glass lantern plates, and then drained off. The moistened sides were then covered with another cover-glass, but separated by means of small wooden diaphragms in order to allow a slight circulation of air. The glasses were kept in an upright position in a cupboard, which was frequently opened.

In a similar way, several other glasses with solutions of potash and caustic soda, mixed in the proportion of 3 to 1, were also prepared and treated in the same way.

After 10 or 15 days crystallisation in most cases began to set in, and the plates were examined and occasionally photographed.

It was most interesting to observe, not only the different forms of crystallisation on the various plates, but also the different forms on the same plate.

In the few attempts made, the form of crystallisation shown in Plate 2, fig. 1, was not exactly reproduced, although in some instances a close approximation was reached.

In conclusion, it may be remarked that the deposit of crystals on the several lenses to which reference has here been made has in no instance been removed at the observatory. The objectives were always sent away to be cleaned, and the method of getting rid of the deposit was to rub the surfaces with material soaked in dilute sulphuric acid. It is, however, satisfactory to know that Messrs. Schott and Genossen no longer manufacture the particular kind of glass which has caused this trouble, and have erased it from their catalogues. The more recently made photo-visual lenses should not, therefore, in future be hampered with this defect.

Before submitting this paper to the Society, I sent it to Mr. H. Dennis Taylor, whose investigations on the theory and practice of photo-visual lenses are so well known. He has kindly written an "Addendum," which is here attached, and which will be found a valuable contribution to the subject of the present paper.

*Addendum by H. Dennis Taylor.**Notes on Dr. Wm. Lockyer's paper on the Permanency of some Photo-visual Lenses.*

Dr. Lockyer kindly submitted to me his paper before publication, with a view to my adding any remarks of my own on this interesting question.

In the first place, I would like to point out that the dates of mounting the instrument given by Dr. Lockyer are not the dates on which the objectives were put together, so that, correctly, at least 12 months should be added to the periods given, on the average.

Dr. Lockyer says that he had not been able to notice any deterioration of the optical performance of any of these objectives after being cleaned up, but that no special tests were employed.

But after cleaning at Messrs. T. Cooke & Sons' works, the objectives were carefully examined and tested for optical deterioration and none whatever was noticed. One would have thought that the crystallising out of some of the alkaline constituents of the glass would have left a network of channels in the glass surfaces, and for the presence of such small inequalities, tests by reflected light should be more appropriate, but we could not see anything. Of course, it is quite possible that the repetition over many years of such crystallisation, supposing it does repeat itself, might deteriorate the surfaces of the lenses sufficiently to cause optical mischief, but so far it has not been apparent.

With regard to the small bundles of glistening crystals forming upon the inner surface of the front lens of baryta light flint, and shown in fig. 2, Plate 2, and figs. 1, 2, and 3, Plate 3, I would like to observe that these never seem to be at all fast to the surfaces, and can always either be blown off or brushed off with a delicate camel-hair brush; and after so brushing them off, the surfaces are just as clean as before, excepting for a little dust that may have found its way in.

As regards the much more noticeable crystallisation on the inner surface of the back lens, I have never had any difficulty in rubbing it off with a soft rag dipped in very weak sulphuric acid, which, after thorough washing off, leaves the surface just like new. The amount of this crystallisation is largely dependent on the dampness or dryness of the situation in which the objective is used, and it would most probably never form at all could we keep the objective always in a dry atmosphere. Moreover, it depends also upon the particular type of crown glass used. I must here point out that the crown glass with a larger amount of alkali than usual, referred to by Dr. Lockyer as O 374, was employed in the 12-in. aperture, $3\frac{1}{2}$ aperture, and one of the two 3-in. aperture O. G.'s, while the other two, of 4-in. aperture, were made out of a borosilicate crown glass, type O 599, of Messrs. Schott's catalogue,





which latter glass is no more likely to develop hygroscopic crystallisation than is the ordinary crown glass used for older type double objective.

We have occasionally had cases, however, where ordinary double objectives that have been used in damp climates have developed the same crystallisation on the interior surface of the crown lens.

Indeed, in damp tropical climates such as that of Calcutta the crystallisation which so frequently develops on the interior surfaces of ordinary crown glass lenses is found, if left too long a time without wiping off, to leave an actual corrosion of the surface in the form of a fine grey veil. The appearance is just like that shown by an imperfectly polished surface, in which the fine pittings caused by the last emeries still survive.

Messrs. Cooke & Sons do not now employ the crown glass O 374, as it wants cleaning more often than is desirable, and use the boro-silicate crown of type O 599, or else a variety of it recently recommended by Messrs. Schott. As regards freedom from secondary spectrum, it is difficult to detect any difference between objectives made of these two different crown glasses.

DESCRIPTION OF PLATES.

PLATE 1.

Figs. 1 and 2. Photographs of two 3-in. lenses after 83 months' use in a laboratory spectroscope. Fig. 1, collimating lens; fig. 2, camera lens.

PLATE 2.

Fig. 1. Photograph of 3.5-in. lens after 40 months' use as a finder to a 3-ft. reflector.

Fig. 2 is a reproduction of a photograph of the same lens, but taken so as to show the markings (white dots near centre) on another surface of the combination.

PLATE 3.

Figs. 1, 2, and 3. Enlarged views (700 diameters) of some of the white markings illustrated in Plate 2, fig. 2.

Figs. 4, 5, and 6. Enlarged views (45, 150, 700 diameters respectively) of parts of one of the groups of crystals shown on Plate 2, fig. 1.

The Nebula H IV 74 Cephei. By Dr. Max Wolf. (Plate 4.)

I have pointed out elsewhere that, as a rule, the nebulae in the Milky Way are encircled by a ring which is void of faint stars, and that this lacuna is the end of a long starless hole, apparently showing the direction of some unknown cosmic motion. I have given a number of examples of this,* the best specimen being the nebula 2 degrees south of π^2 Cygni.

On photographing the Nebula H IV 74 Cephei (= N.G.C. 7023 : $\alpha = 21^{\text{h}} 0^{\text{m}} 30^{\text{s}}$ $\delta = +67^\circ 46' 2''$ (1900.0)) with the 28-inch reflector of the Königstuhl Astrophysical Observatory, I was surprised to find a striking specimen of this phenomenon, the nebula being surrounded by a lacuna absolutely empty of faint stars. In spite of the small field of the reflector-plate, there was evidence that the cavity was the end of a channel entering the picture almost exactly from the south.

This nebula was photographed by the late Dr. Roberts (vol. ii., plate 24). He says: "The nebula appears in a region almost void of stars" (p. 157).

I then endeavoured to photograph the channel with the large field of my 16-inch cameras. But the weather was very unfavourable during this spring and summer, and the sky always so hazy, that three nights were lost in these attempts. The last of these trials, on July 7 (exposure 3 hours 22 minutes), gave relatively the best picture, a reproduction of which is given on Plate 4, fig. 1. The scale is about 70 mm.† for 1 degree. As may be seen, the channel is directed in its first part almost exactly from south to north. At a distance of about 1 degree from the centre of the nebula the channel is divided into two branches. The eastern branch is perhaps shorter, and the western longer, ending at a distance of about $1\frac{3}{4}$ degrees from the nebula by becoming gradually filled up with stars. The somewhat round cavity encircling the nebula has a diameter of about half a degree.

We have therefore a further example of the rule that a nebula is encircled by a lacuna void of stars, which lacuna is the end of an empty channel.

The nebula itself is a very remarkable object. In many respects it resembles in form the π^2 Cygni nebula. On the other hand, the faint bands of nebulosity parallel with the brighter bands are very much like those in the Orion nebula. This parallelism gives an indication of some kind of wave formation in the nebulous material. These are especially visible at the north-west side, three parallel waves, each nearly half the brightness of the inner preceding wave. I am especially struck by the gradual fading of the light of the nebulous matter from the centre, producing the impression that nebulous matter is spread all over

* *Astron. Nachr.*, 3848; *M.N.*, *R.A.S.*, lxiv., No. 9; *Public. Astrophys. Inst.*, *Königstuhl, Heidelberg*, vols. i. and ii., etc.

† In the reproduction 48 mm. = 1° .



FIG. 2

NEBULA H II V. 774 CEPHEI. MAX WOLF.



FIG. 1.

the lacuna, but has insufficient luminosity to be visible. I do not know any nebula in the sky which shows this more clearly.

I also give a somewhat enlarged reproduction of a picture of the nebula itself, taken with the 28-inch reflector (Plate 4, fig. 2). The photograph was taken April 18, 1907, with an exposure of 40 minutes. The scale on the reproduction is about 1 mm. to 21 seconds of arc.*

I may perhaps mention two peculiarities common to this nebula, to the π^2 Cygni nebula, and to perhaps all other similarly surrounded by lacunæ. First: the long channels are all nearly straight and clean in the vicinity of the nebula, and become curved and partly filled up with stars at a greater distance from it. Secondly: the channel is simple at the end nearest the nebula, and divided into two or three complicated arms at the end further removed.

* In the reproduction 1 mm. = about $30''\cdot6$.

Heidelberg, Astrophysical Observatory:
1907 July 27.

Occultation of the Hyades. By Walter Heath, M.A.

In order to determine the longitude of my observatory I have recently compared twenty-three occultation observations made by me with the corresponding Greenwich observations, and I find a discordance in the case of the reappearance of two stars of the Hyades on 19th September 1905. I have therefore compared the results with some observations published in *A.N.*, 4088; the following are the particulars. The results in brackets are derived from observations at the bright limb.

1905 Sept. 18	Utrecht	f Tauri	$\cdot95\Delta\alpha + \cdot41\Delta\delta = (10^{\circ}20)$
" "	"	"	$\cdot99$ " + $\cdot27$ " = $8^{\circ}44$
" "	Jena	"	$\cdot95$ " + $\cdot39$ " = $8^{\circ}26$
" 19	"	γ Tauri	$\cdot42$ " + $\cdot95$ " = $(5^{\circ}78)$
" "	"	"	$\cdot84$ " - $\cdot57$ " = $3^{\circ}97$
" "	Greenwich	θ_1 Tauri	$\cdot94$ " + $\cdot37$ " = $1^{\circ}71$
" "	"	D.M. 15° , 633	$\cdot94$ " - $\cdot35$ " = $1^{\circ}36$
" "	Cobham	θ_1 Tauri	$\cdot94$ " + $\cdot38$ " = $5^{\circ}12$
" "	"	D.M. 15° , 633	$\cdot95$ " - $\cdot35$ " = $6^{\circ}22$

Note.—For Cobham the longitude assumed was $23^{\circ}6''$ W., latitude $51^{\circ}19'39''$, height above sea 180 feet. The sidereal times observed were $4^h 27^m 22^s\cdot49$ and $4^h 45^m 2^s\cdot02$ after correction.

Uplands, Cobham, Surrey:
1907 October 18.

Disappearance of Saturn's Ring System, 1907 October.

By R. T. A. Innes.

Thanks to the assistance of Sir David Gill and the Witwatersrand Council of Education (Mr. Th. Reunert, chairman), I have within the last few days erected a 9-in. refractor by Grubb.

The disappearance of Saturn's rings was watched with this instrument on the 3rd October 1907. An exact copy of the notes made reads as follows :

1907 Oct. 3, 6.45 p.m. twilight (4.45 p.m. G.M.T.). Saturn's ring distinctly seen by myself and several visitors. It was very faint and only seemed to be about half of its usual length. Definition medium, planet low.

8.45 p.m. (6.45 p.m. G.M.T.). The ring is invisible. The bright equatorial band was crossed by a sharp dark line which just lay to the N. of Saturn's equator. This dark line had been seen on preceding nights, but on this occasion it seemed to be sharper and darker. Two satellites, about 2" or 3" apart, followed Saturn.

9.30 p.m. (G.M.T. 7.30 p.m.). Ring distinctly seen, but like a ghost. Care taken to eliminate subjective effects. Definition very good.

10 p.m. (8.0 G.M.T.). Ring still glimpsed. Preceding part of ring modified by two beads, one twice as large as the other (Enceladus and Mimas). My son's description is "Ring visible on both sides, extending about three-quarters diameter of planet. Nearer and brighter satellite is half way along ring and touches the northern side. Fainter satellite precedes end of ring."—(E. A. I.)

11.45 p.m. (9.45 G.M.T.). Quite doubtful if ring really seen. Mimas and Enceladus very close together. My son, however, was quite certain that he held the ring steadily. His words are "Ring very faint, but ended off sharply. Fainter satellite is preceding."—(E. A. I.) Definition perfect.

12.30 p.m. (10.30 G.M.T.). No suspicion of ring; only one satellite seen prec. "Ring not seen with any certainty. The first of the satellites following Saturn getting too close."—(E. A. I.) Definition very good.

Thus at	3 Oct. 1907	4.45 G.M.T.	Ring quite easy.
		7.30 "	Ring difficult but distinct.
		8.0 "	Ring still seen.
		9.45 "	Ring still glimpsed.
		10.30 "	Ring invisible.

So that, as seen in a 9-in. refractor under circumstances of good definition, the ring system became invisible soon after 9.45 and before 10.30 G.M.T. As the ring was easy to see at 4.45, and got difficult as quickly, the Earth must have passed through its plane soon after invisibility.

Observations during the period that the dark sides of the rings are exposed to the Earth answer the question as to whether the rings are composed of solid particles or of vaporous matter. If the latter, the edges at least of the rings would be seen.

Johannesburg:
1907 October 5.

Observations of the Satellite of Neptune, from photographs taken at the Royal Observatory, Greenwich, between 1906 December 27 and 1907 April 24.

(Communicated by the Astronomer Royal.)

The following measures of position-angle and distance of Neptune's satellite were made from photographs taken with the 26-in. refractor of the Thompson equatorial. The occulting shutter was used as in previous years. The photographs were taken by Messrs. Davidson, Eduey, or Melotte, and were measured in a position micrometer in direct and reversed position by Messrs. Davidson and Melotte. The tabular positions with which comparison is made were computed from the data given in the *Connaissance des Temps*, based on Dr. Hermann Struve's elements, the eccentricity of the orbit being neglected.

A discussion of these residuals gives the following differences from Dr. Hermann Struve's elements in the sense Tabular - Observed :

$$du = -1^{\circ}03 \quad dN = -0^{\circ}98 \quad dI = -0^{\circ}18 \quad da = -''008$$

giving for the epoch 1907.2

$$a = 16''279 \quad N = 188^{\circ}68 \quad I = 116^{\circ}69.$$

Neptune and Satellite.

Position-angle and Distance, from photographs taken with the 26-in. Refractor.

Date and G.M.T.				Position-angle.			Distance.		
				Obs.	Tab.	T-O.	Obs.	Tab.	T-O.
1906.									
d	h	m	s						
Dec. 27	10	57	45	305°13	305°07	-0°06	14''53	14''72	+0''19
1907.									
Jan. 17	10	14	43	105°43	106°11	+0°68	16'44	16'47	+0'03
	17	10	42 11	104°02	105°30	+1°28	16'54	16'52	-0'02
	17	11	7 30	102°39	104°57	+2°18	16'75	16'57	-0'18
	30	10	30 31	44°20	45°99	+1°79	12'69	12'80	+0'11
	30	10	56 6	43°18	44°76	+1°58	12'60	12'70	+0'10
	30	11	22 51 (a)	43°40	43°43	+0°03	12'84	12'59	-0'25

Position-angle and Distance—continued.

Date and G.M.T.					Position-angle.			Distance.		
					Obs.	Tab.	T-O.	Obs.	Tab.	T-O.
1907.										
	d	h	m	s						
Feb.	1	12	46	8	269°00	269°10	+0°10	16"82	16"73	-0"09
	7	10	34	23 (b)	266°96	267°77	+0°81	16°53	16°65	+0°12
	21	11	2	29	115°59	117°16	+1°57	15°71	15°30	-0°41
	28	8	23	33	70°27	72°94	+2°67	15°39	15°42	+0°03
	28	8	54	19	71°73	71°93	+0°20	15°53	15°32	-0°21
	28	9	29	47 (c)	69°48	70°75	+1°27	14°96	15°20	+0°24
Mar.	1	9	40	41	356°64	357°01	+0°37	10°92	10°99	+0°07
	1	10	3	48	354°77	355°52	+0°75	10°73	11°01	+0°28
	1	10	25	37	352°86	354°13	+1°27	10°98	11°04	+0°06
	1	10	44	18	352°63	352°94	+0°31	11°10	11°06	-0°04
	23	9	6	19 (b)	93°73	93°30	-0°43	16°09	16°43	+0°34
	23	9	36	54 (a)	91°43	92°44	+1°01	16°68	16°42	-0°26
	23	10	6	38 (a)	90°23	91°61	+1°38	16°40	16°42	+0°02
	25	9	26	39 (d)	316°61	318°15	+1°54	12°88	12°79	-0°09
	27	9	1	44	218°08	218°66	+0°58	12°01	11°97	-0°04
	27	9	25	8	216°54	217°43	+0°89	12°10	11°89	-0°21
	27	9	56	16	214°39	215°76	+1°37	11°81	11°95	+0°14
	27	10	23	35 (e)	214°27	214°26	-0°01	11°74	11°69	-0°05
	28	8	58	37	133°22	135°42	+2°20	13°11	13°02	-0°09
	28	9	33	48 (f)	134°36	133°88	-0°48	13°01	13°16	+0°15
Apr.	6	9	50	47	301°44	302°67	+1°23	14°24	14°25	+0°01
	24	9	32	40	283°83	286°05	+2°22	15°51	15°69	+0°18

(a) Satellite faint and diffused.

(b) Satellite very faint and diffused.

(c) Photographic speck on Satellite.

(d) Very faint.

(e) Satellite diffused

(f) Very diffused. On fringe of secondary spectrum.

Royal Observatory, Greenwich:

1907 November 7.

Observations of Minor Planets, from photographs taken with the 30-in. Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich, during the year 1906.

(Communicated by the Astronomer Royal.)

The following positions of minor planets were obtained from photographs taken with the 30-in. reflector during the year 1906.

The plates were measured with the astrographic micrometer. Six reference stars were, as a rule, measured with the planet, their positions being derived when possible from the Catalogues of the Astronomische Gesellschaft, or from the Radcliffe Catalogue, 1890.

The positions given are not corrected for Parallax.

Log Parallax Correction = log Parallax Factor — log Δ .

Date and G. M. T. 1906. d h m s	Apparent R. A. h m s	Apparent Dec. ° ' "	Log Parallax Factor. R. A.	Dec.
(324) Bamberga.				
Apr. 14 11 1 14	12 39 36.97	- 17 13 48.1	- 8.223	+ 0.912
19 11 39 24	12 35 28.10	16 51 3.6	+ 8.943	0.909
25 10 33 53	12 30 54.16	16 22 50.6	+ 8.397	0.910
26 10 33 3	12 30 10.98	16 18 4.7	+ 8.500	0.909
(278) Paulina.				
Apr. 25 10 13 58	13 29 30.55	- 1 0 7.1	- 9.004	+ 0.842
26 11 24 48	13 28 39.43	0 59 32.3	+ 8.283	0.842
27 10 30 35	13 27 51.53	0 59 8.2	- 8.770	0.842
(191) Kolga.				
Apr. 28 11 0 8	14 21 35.91	+ 0 27 10.1	- 8.955	+ 0.833
(146) Lucina.				
Apr. 28 11 42 9	14 22 38.29	+ 3 16 50.5	- 8.408	+ 0.815
(443) Photographica.				
May 24 10 31 24	14 29 8.52	- 8 17 18.3	+ 8.162	+ 0.879
31 10 9 23	14 24 55.15	7 58 8.0	+ 8.463	0.878
(65) Cybele.				
May 24 11 16 15	14 45 18.23	- 11 0 58.8	+ 8.778	+ 0.890
31 10 37 31	14 41 19.64	10 45 10.0	+ 8.687	0.889
(148) Gallia.				
May 24 11 51 35	15 2 27.91	+ 18 46 52.8	+ 8.971	+ 0.679

Date and G.M.T. 1906. d h m s				Apparent R.A. h m s	Apparent Dec. ° ' "	Log Parallax R.A.	Factor, Dec.
(504) Cora.							
May 31	11	16	57	15 35 50.38	- 4 25 21.0	+8.381	+0.861
(92) Undine.							
May 31	11	49	17	15 46 36.07	- 9 52 12.8	+8.776	+0.885
(487) Venetia.							
June 26	11	0	51	17 29 23.80	- 15 39 33.1	-8.299	+0.907
(374) Burgundia.							
June 22	11	47	58	18 3 21.22	- 11 55 20.9	-8.359	+0.894
	26	11	33 56	17 59 52.17	11 47 15.6	-8.167	0.894
(409) Aspasia.							
June 22	12	18	7	18 35 22.41	- 12 42 26.5	-8.360	+0.897
	22	12	51 59	18 35 21.17	12 42 18.9	+8.515	0.897
	25	11	0 28	18 32 34.52	12 30 22.0	-9.103	0.893
	25	11	28 31	18 32 33.44	12 30 18.1	-8.918	0.895
	26	12	1 21	18 31 34.61	12 26 19.1	-8.294	0.898
(28) Bellona.							
June 22	12	18	7	18 33 10.10	- 12 44 23.3	-8.418	+0.897
	22	12	51 59	18 33 8.96	12 44 23.9	+8.469	0.897
	25	11	6 2	18 30 37.38	12 50 4.3	-9.065	0.895
	25	11	28 31	18 30 36.50	12 50 5.5	-8.901	0.896
	26	12	1 21	18 29 43.15	12 52 13.3	-8.360	0.896
(122) Gerda.							
June 26	12	33	45	18 34 29.04	- 20 52 29.8	+8.437	+0.922
(51) Nemausa.							
June 26	13	26	8	18 47 10.66	- 6 16 13.3	+8.950	+0.869
(7) Iris.							
July 28	12	27	29	20 33 18.57	- 11 26 56.1	+8.442	+0.892
	31	12	44 57	20 30 10.29	11 31 25.5	+8.908	0.891
(378) Holmia.							
Aug. 14	11	52	22	20 34 43.06	- 7 18 36.7	+8.885	+0.874
	21	10	50 11	20 29 29.86	7 45 2.2	+8.462	0.877
	22	10	25 22	20 28 49.23	7 48 55.8	-7.509	0.877

Date and G.M.T. 1906. d h m s				Apparent R.A. h m s	Apparent Dec. ° ' "	Log Parallax R.A.	Factor. Dec.
(434) Hungaria.							
July	25	13	3 36	21 31 19'97	+17 30 48'3	-8'428	+0'689
Aug.	7	11	37 33	21 22 6'04	14 37 43'9	-8'839	0'722
	14	12	53 0	21 16 23'60	12 20 24'7	+9'033	0'746
	15	12	56 5	21 15 35'25	11 58 45'8	+9'080	0'750
	21	11	9 14	21 11 0'89	9 41 8'5	-7'812	0'766
(480) Hansa.							
Aug.	14	12	24 42	21 14 5'76	+18 43 19'0	+8'838	+0'677
	15	12	34 9	21 13 13'47	18 40 17'7	+8'963	0'680
	21	11	44 56	21 8 9'79	18 16 20'1	+8'756	0'682
	22	10	46 34	21 7 22'50	18 11 33'0	-8'526	0'681
Sept.	7	9	18 9	20 56 11'42	16 20 30'8	-8'751	0'703
(136) Austria.							
Aug.	15	13	12 59	21 50 47'37	- 0 25 40'9	+8'947	+0'838
	21	12	1 51	21 45 54'03	1 21 51'1	+8'349	0'844
	22	11	24 48	21 45 6'31	1 31 37'2	-8'482	0'845
(386) Siegena.							
Aug.	7	11	51 38	22 1 18'45	+ 0 57 40'8	-9'023	+0'841
	14	13	39 13	21 56 44'93	- 0 14 0'0	+9'059	0'837
	15	13	32 2	21 56 4'35	- 0 24 54'9	+9'042	0'838
	21	12	31 41	21 51 56'19	- 1 33 51'5	+8'770	0'845
	22	12	6 4	21 51 14'90	- 1 45 44'3	+8'407	0'846
(308) Polyo.							
Aug.	22	12	27 8	22 7 8'88	- 7 39 40'7	+8'549	+0'876
	28	11	39 36	22 2 25'18	8 15 29'6	+7'509	0'879
(42) Isis.							
Aug.	28	14	46 31	23 44 1'69	-20 22 56'9	+9'165	+0'914
(26) Proserpina.							
Aug.	29	14	0 16	23 25 51'28	- 9 7 47'0	+9'010	+0'881
(478) Tergeste.							
Sept.	11	10	7 45	23 3 21'06	+12 44 57'6	-9'184	+0'746
	25	11	40 33	22 53 35'71	11 10 17'6	+9'006	0'756
	26	11	39 22	22 52 58'04	11 2 52'4	+9'025	0'757
	27	11	21 1	22 52 21'54	10 55 29'7	+8'924	0'757
Oct.	10	10	27 36	22 45 43'85	9 16 16'1	+8'953	0'771

Date and G.M.T. 1906. d h m s	Apparent R.A. h m s	Apparent Dec. ° ' "	Log Parallax Factor. R.A.	Factor. Dec.
(108) Hecuba.				
Sept. 26 12 16 15	0 29 18.35	+ 4 50 59.4	+7.983	+0.804
27 11 46 27	0 28 35.36	4 47 22.2	-8.483	0.804
Oct. 16 12 0 41	0 15 1.30	3 36 19.3	+9.119	0.816
(47) Aglaia.				
Sept. 26 12 42 44	0 58 33.13	+ 7 21 20.3	+7.809	+0.785
27 12 6 35	0 57 44.66	7 18 29.5	-8.653	0.786
Oct. 16 12 19 46	0 41 33.92	6 16 6.2	+9.084	0.796
23 10 20 58	0 36 17.53	5 54 41.8	-8.206	0.796
(175) Andromache.				
Sept. 26 13 22 52	1 18 13.42	+ 7 14 39.6	+8.586	+0.786
27 12 21 8	1 17 32.63	7 11 39.4	-8.724	0.787
Oct. 23 10 41 27	0 57 44.73	5 42 55.6	-8.247	0.797
(153) Hilda.				
Oct. 16 12 52 59	1 19 45.76	+13 15 40.6	+9.065	+0.738
23 11 48 14	1 15 32.48	12 40 20.3	+8.803	0.740
(500) Selinur.				
Dec. 6 10 38 13	5 14 52.34	+31 53 24.5	-9.240	+0.500
1907.				
Jan. 2 8 51 22	4 47 56.08	29 14 39.5	-9.107	0.535
(19) Fortuna.				
1906.				
Dec. 14 11 24 9	5 41 7.53	+21 6 39.2	-8.894	+0.649

Royal Observatory, Greenwich :

1907 November 8.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the year 1906.

(Communicated by the Astronomer Royal.)

The measures were made with a bifilar position micrometer on the 28-inch refractor, focal length 28 feet. The power generally employed was 670. When bright stars were observed a blue glass shade was usually employed to diminish the light and irradiation. The observations were made in variously coloured fields or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz. :—

L.	Mr. Lewis	B.	Mr. Bryant
W. B.	Mr. Bowyer	H. F.	Mr. Furner

The main portion of the measures are of pairs discovered by Hough, which usually consist of a bright star with a faint companion. The remaining measures are of stars selected from the catalogues of W. Struve, Otto Struve, Burnham, Hussey, and Aitken.

In general the present list of measures is confined to stars of which the separation is under 4" or which show orbital motion.

The following stars, which are not included in the list of measures, have also been observed.

Hough Stars.

20	116	323	387	446 AC	501	573
26	117	327	394	448	519	576 AC
28	131	337 AB	400	452 AB	523	586
29	204	337 AC	406 AB	452 AC	534	597
30	236	343	406 AC	460	539	603
31	240	347	412	465	543	604
32	259	348	416	473	548	606
38	269	349	423	475 AC	550	611
39	281	362 AB	425	476	551	613
45	297	362 AC	426	477	552	615
64	302	365	433	478	553	616
91	305 AB	372	434	486	557	617
115	305 AC	377	440	487	570	

Struve Stars.

877	1934	2185 AB	2476 AC	2690 AB	2818 R
1297	1965	2185 AC	2585 AC	2690 AD	2824

*Micrometric Observations of Double Stars at the
Royal Observatory, Greenwich.*

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	° '	°	"				
β 1093	0 16	79 31	73°1	0'29	1	7'3 8'2	'882	B.
β 779	0 23	66 55	257°1	0'78	1	8'5 9'0	'882	B.
Ho 212	0 31	94 5	244°4	0'24	1	6'0 6'0	'882	B.
Hu 411	0 33	67 50	279°3	0'67	3	8'5 8'5	'884	W. B.
Ho 306	0 43	64 56	165°3	1'21	3	8'5 8'8	'884	W. B.
Σ 73	0 50	66 52	28°1	0'97	3	6'2 6'8	'860	B.
	...	...	27°9	0'99	3	...	'879	W. B.
Ho 307	0 52	58 17	88°8	3'01	1	9'5 9'7	'928	W. B.
Σ 113	1 15	91 0	357°5	1'56	1	6'2 7'2	'882	B.
Ho 310	1 21	61 55	359°0	1'52	2	9'0 9'0	'882	W. B.
Ho 9	1 24	68 45	97°2	3'12	2	9'0 11'0	'909	W. B.
Σ 138	1 31	82 50	38°7	1'62	2	7'3 7'3	'904	B.
Σ 183 AB	1 50	61 39	359°1	0'36	2	7'5 8'2	'904	B.
AC	...	...	162°9	5'19	2	7'5 8'7	'904	B.
Σ 186	1 51	88 37	36°8	0'68	1	7'2 7'2	'882	B.
Ho 12	1 57	55 46	97°2	3'75	1	8'0 10'7	'068	H. F.
Ho 315	2 34	91 58	359°7	1'38	2	8'0 8'2	'454	B.
Σ 305	2 42	71 1	315°0	3'30	2	7'3 8'2	'901	W. B.
	...	...	314°4	2'88	1	...	'925	B.
Ho 317	2 52	73 7	304°5	3'36	2	8'1 11'0	'456	W. B.
Ho 318	2 54	73 19	27°6	3'22	2	9'1 9'1	'454	B.
Σ 367	3 9	89 37	209°0	0'49	1	8'0 8'0	'882	B.
Ho 320	3 16	89 9	169°2	2'08	1	8'0 10'5	'025	B.
Aitken 979	3 20	59 35	274°0	1'45	1*	9'2 10'0	'890	W. B.
Ho 14	3 28	62 1	201°0	1'88	1	8'2 8'7	'019	L.
Ho 324	3 44	75 18	162°8	0'68	1	8'1 8'3	'019	L.
β 1232	4 4	61 3	4°5	0'48	1	8'4 9'3	'019	L.
Ho 328	4 12	70 33	245°1	0'47	1	7'0 7'0	'068	H. F.
Ho 15	4 19	60 5	323°4	0'79	2	8'0 8'0	'041	W. B.
Hu 304	4 19	80 44	38°9	0'31	1	5'9 5'9	'025	B.
Ho 332	4 38	69 31	127°1	1'32	1	9'0 9'0	'025	B.
Ho 333	4 38	69 55	160°8	2'55	1	9'2 9'3	'025	B.
Ho 17	4 54	59 7	56°2	4'11	2	8'0 10'0	'065	W. B.
Ho 222	4 54	58 33	223°1	2'11	1	7'7 10'5	'022	W. B.
Ho 224 AB	4 59	61 24	297°2	1'46	2	9'0 10'7	'137	H. F.
Ho 334	5 12	67 16	183°7	2'12	2	8'1 10'2	'055	W. B.
Ho 225	5 17	77 25	115°8	0'51	2	8'0 8'1	'100	W. B.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	° '	°	"				
Ho 226 AB	5 21	62 28	239°0	0°62	4	7°0 7°0	°074	W. B.
$\frac{AB}{2}$ & C	...	...	273°6	23°57	3	7°0 10°5	°087	W. B.
Ho 335	5 27	63 17	114°1	3°19	2	9°0 10°5	°086	W. B.
Σ 749	5 31	63 6	169°3	0°81	1	7°0 7°1	°255	B.
Hu 825	5 34	54 3	339°5	0°30	1	7°8 8°0	°255	B.
Ho 510	5 39	56 19	241°2	1°31	1	9°0 9°2	°255	B.
Hu 38	5 40	67 8	138°0	0°77	1	8°6 8°8	°255	B.
Hu 39	5 42	68 10	65°5	0°43	1	8°4 8°5	°255	B.
Hu 40	5 46	69 53	8°0	3°29	1	8°5 9°5	°255	B.
Ho 228	6 1	77 30	270°2	2°38	2	8°0 11°0	°064	W. B.
Ho 22	6 8	79 43	198°1	0°72	2	8°0 8°0	°140	B.
Ho 230	6 14	76 11	60°0	1°89	4	8°3 10°5	°085	W. B.
Ho 232	6 17	75 17	356°5	2°58	1	9°5 11°0	°068	H. F.
Ho 233	6 18	73 26	38°3	2°24	2	8°2 11°0	°041	W. B.
Hu 702	6 19	55 33	318°3	0°93	3	8°5 9°0	°273	W. B.
OΣ 141	6 25	72 2	139°6	2°12	2	7°9 9°6	°130	W. B.
Σ 945	6 34	48 54	269°9	0°75	1	7°1 8°0	°255	B.
Σ 3117	6 36	80 10	94°2	0°66	1	8°9 9°4	°019	L.
Σ 3118	6 37	80 5	174°3	2°97	1	9°0 9°5	°019	L.
Ho 238	6 41	71 41	182°4	0°49	2	8°3 8°3	°155	W. B.
OΣ 156	6 42	71 42	298°1	0°56	3	6°5 7°0	°150	W. B.
Ho 239	6 45	75 12	139°9	0°59	1	8°3 8°3	°145	W. B.
Ho 27	6 50	69 47	125°7	3°27	2	9°0 9°0	°041	W. B.
Ho 342	6 58	76 46	84°9	1°02	3	8°0 8°8	°141	W. B.
Ho 518	7 5	59 29	143°6	2°97	2	8°0 10°0	°141	W. B.
Σ 1037 AB	7 7	62 37	297°9	0°60	1	7°1 7°1	°192	L.
AC	...	...	111°5	17°24	1	7°1 12°0	°192	L.
Ho 33	7 15	67 40	324°5	2°69	2	9°0 12°0	°099	W. B.
Ho 243	7 17	60 34	166°4	2°29	1	9°3 9°5	°164	W. B.
Ho 345 AB	7 17	67 45	284°0	1°16	1	9°0 10°0	°236	H. F.
Ho 346	7 21	71 40	60°2	13°18	2	7°0 11°8	°221	H. F.
Ho 34	7 26	68 44	10°5	2°45	2	9°5 9°5	°078	W. B.
Hu 707	7 29	68 11	27°2	2°23	2	8°6 12°0	°221	H. F.
Hu 457	7 35	66 33	143°6	2°30	1	8°5 12°3	°192	L.
Ho 247	7 41	68 39	106°9	0°54	1	7°5 8°0	°140	W. B.
Ho 36	7 42	64 19	123°1	0°65	2	8°5 8°5	°267	W. B.
Ho 250	7 52	68 47	168°3	0°52	2	7°0 9°0	248	H. F.
β 581 $\frac{AB}{2}$ & C	7 59	77 28	191°9	4°46	2	8°0 11°0	°217	B.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	° '	°	"				
Ho 351	8 2	68 51	228°9	2'32	1	7'0 11'7	'236	H. F.
Σ 1187	8 4	57 31	43'3	2'22	2	7'1 8'0	'261	W. B.
Σ 1196 AB	8 7	72 4	348'3	1'03	1	5'0 5'7	'101	B.
	...	...	347'0	1'04	2	...	'233	H. F.
	...	...	346'1	1'09	2	...	'251	W. B.
AC	...	...	111'2	5'19	1	5'0 5'5	'101	B.
	...	...	108'9	5'15	2	...	'233	H. F.
	...	...	109'3	5'36	2	...	'251	W. B.
BC	...	...	120'0	6'18	1	5'7 5'5	'101	B.
	...	...	122'6	6'22	2	...	'251	W. B.
Ho 524	8 11	71 2	337'1	4'10	2	8'0 11'0	'203	W. B.
Hu 626	8 14	57 23	155'3	2'88	1	8'0 12'0	'315	W. B.
Hu 855	8 17	76 33	225'0	1'42	1	9'2 10'8	'268	L.
Ho 525	8 18	69 42	334'4	0'49	1	8'5 8'5	'268	L.
Hu 714	8 21	57 30	344'3	0'53	1	8'6 9'2	'268	L.
Ait. 551	8 24	92 13	56'5	0'24	1	7'4 7'5	'312	B.
Hu 627	8 25	55 10	268'1	0'75	1	9'0 10'0	'315	W. B.
Hu 717	8 27	57 14	52'7	0'45	2	8'8 9'0	'307	L.
Hu 858	8 33	77 43	171'6	0'91	2	9'1 9'8	'248	H. F.
Ho 354	8 37	63 37	177'6	0'97	2	8'2 8'2	'307	L.
Ho 355	8 38	92 22	185'4	0'36	1	8'0 8'0	'312	B.
Σ 1273 AC	8 42	83 15	236'0	2'85	1	3'3 7'8	'270	W. B.
Ho 360	8 55	67 11	149'9	3'60	4	8'0 12'0	'243	W. B.
Ho 41	8 59	92 2	71'4	4'08	2	9'0 10'0	'217	B.
Ho 42	9 9	56 4	6'8	1'41	3	9'5 9'5	'228	W. B.
Σ 3121	9 13	61 2	216'8	0'42	2	7'5 7'8	'251	W. B.
	...	...	211'7	0'57	2	...	'284	B.
Ho 43	9 14	68 48	298'7	0'39	1	8'0 8'5	'315	W. B.
	...	...	288'9	0'27	1	...	'345	L.
Ho 364	9 14	66 42	334'8	3'97	2	8'2 11'2	'171	W. B.
Σ 1348	9 20	83 15	318'5	1'76	2	7'5 7'6	'274	W. B.
Σ 1355	9 22	83 21	335'1	2'45	2	7'2 7'2	'284	W. B.
Ho 366	9 23	58 8	14'8	0'69	2	8'5 8'7	'326	L.
Σ 1356	9 23	80 34	114'4	0'76	2	6'2 7'0	'284	B.
Ho 367	9 28	61 14	257'9	32'18	2	6'2 11'0	'214	W. B.
Hu 1128	9 30	53 47	36'8	5'40	1	5'5 14'0	'345	L.
Ho 253	9 43	79 30	293'6	1'13	2	7'0 12'0	'226	W. B.
Hu 631	9 59	56 55	271'0	0'73	1	7'0 8'6	'312	B.
	...	...	272'2	0'74	2	...	'326	L.

Star's Name.	R. A. 1910.	N. P. D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	° '	°	"				
Hu 634	10 11	56 24	161°3	1'69	2	8·4 9·8	'233	H. F.
Hu 875	10 13	52 2	62°3	0·96	1	7·0 9·8	'307	L.
	...	...	71°6	0·93	1	...	'315	W. B.
Hu 879	10 23	52 50	234°6	0·42	1	4·0 6·5	'312	B.
Σ 1439	10 25	68 44	112°8	1'86	3	8·0 8·5	'275	H. F.
Hu 880	10 26	52 23	124°9	0'80	1	9·0 9·7	'312	B.
Hu 636	10 27	56 42	204°1	1'86	1	9·0 10·5	'260	H. F.
Ho 374	10 45	66 41	271°0	3'71	3	8·4 12°0	'220	W. B.
Ho 376	10 48	66 19	218°4	3'17	2	8·8 10°0	'195	W. B.
Ho 48	10 59	66 22	8°7	1'93	3	8·0 11°2	'288	W. B.
Σ 1536	11 19	78 58	51°9	2'39	1	3·9 7·1	'255	B.
Ho 51	11 27	81 38	176°2	2'47	1	7°0 12°0	'318	W. B.
Hu 888	11 38	68 25	142°2	0'64	2	8·4 8·9	'266	W. B.
Lewis	11 54	59 2	9°2	0'84	1	7°0 11°5	'345	L.
Hu 890	11 57	78 10	64°2	1'38	3	9°0 10°0	'261	W. B.
Ho 535	11 58	67 44	139°6	2'18	3	8°0 12°0	'267	W. B.
Ho 53	12 19	75 35	296°4	2'11	3	8°0 11°7	'330	W. B.
Σ 1639	12 20	63 55	357°2	0'37	2	6·7 7·9	'370	B.
Σ 1643	12 23	62 23	39°1	2'29	1	8·7 9·2	'268	L.
Σ 1647	12 26	79 47	223°9	1'59	1	7·5 7·8	'268	L.
	...	...	224°2	1'45	3	...	'303	W. B.
Ho 54 BC	12 37	79 37	142°7	2'14	1	7°0 10°0	'318	W. B.
BD	...	...	64°6	10'44	1	10°0 13°5	'318	W. B.
Hu 892	12 38	74 59	160°7	0'78	2	9·3 9·3	'284	B.
Hu 893	12 43	77 13	33°8	1'50	2	9·1 9·1	'284	B.
Hu 894	12 49	76 20	144°7	1'08	2	9·1 9·1	'284	B.
Ho 257	13 1	63 17	154°6	1'75	2	8·8 8·9	'297	W. B.
OΣ 261	13 8	57 26	344°8	1'37	1	6·9 7·4	'427	B.
Ho 260	13 19	60 8	321°2	0'70	3	8·3 8·5	'371	W. B.
OΣ 269	13 29	54 38	217°3	0'37	1	6·5 7°0	'427	B.
Hu 645	13 35	68 5	30°4	0'88	1	9·2 9·6	'345	L.
OΣ 278	14 9	45 24	76°4	0'28	1	7·5 7·7	'427	B.
Ho 541	14 16	77 25	91°6	2'12	5	9·3 10°2	'377	W. B.
Σ 1834	14 17	41 5	2°2	0'14	1	7·1 7·2	'427	B.
Aitken 1105	14 23	58 58	185°6	1'01	3	9·1 9·4	'417	W. B.
Ho 542	14 23	68 59	252°7	0'53	2	6·8 8·8	'370	B.
Σ 1865	14 37	75 54	145°9	0'47	3	3·5 3·9	'401	B.
OΣ 285	14 42	47 14	126°1	0'31	1	7·1 7·6	'427	B.
Ho 263	14 44	65 32	175°4	1'07	2	7°0 10°0	'467	W. B.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	° '	°	"				
Ho 389	14 48	69 20	95°1	1°51	3	7°0 9°3	'372	W. B.
O Σ 287	14 48	44 42	321°6	1°04	1	7°5 7°6	'427	B.
O Σ 288	14 49	73 56	188°7	1°61	2	6°4 7°1	'362	W. B.
Σ 1909	15 1	41 57	244°6	4°60	2	5°2 6°1	'701	L.
Ho 60	15 10	54 47	35°9	0°41	2	7°5 7°6	'467	W. B.
Σ 1926	15 11	51 22	249°9	0°94	1	6°1 8°4	'671	L.
Σ 3091	15 11	94 33	25°5	0°25	1	7°7 7°7	'465	B.
Ho 547	15 12	72 52	297°1	5°55	2	7°9 12°0	'458	W. B.
Σ 1934	15 14	45 56	27°7	7°35	2	8°5 8°5	'701	L.
Σ 1944	15 23	83 36	325°3	1°22	2	7°5 8°1	'418	W. B.
O Σ 296	15 23	45 41	302°4	1°58	2	7°0 8°6	'701	L.
Lewis	15 24	43 32	334°9	3°06	2	9°5 9°8	'701	L.
Σ 1954	15 30	79 9	186°2	3°30	2	3°2 4°1	'458	W. B.
Ho 63	15 32	61 19	304°5	1°53	1	9°0 9°2	'312	B.
	...	...	307°6	1°24	2	...	'437	W. B.
O Σ 298	15 33	49 54	13°0	1°29	1	7°0 7°3	'671	L.
Hu 580	15 38	70 2	69°5	0°20	2	5°0 5°0	'446	B.
Ho 399	15 52	60 12	119°8	2°97	3	7°5 10°0	'448	W. B.
O Σ 303	15 57	76 28	144°9	0°81	3	7°4 7°9	'446	W. B.
Σ 1998	15 59	101 8	358°0	0°35	1	4°9 5°2	'465	B.
Σ 2021	16 9	76 14	336°2	4°08	2	6°7 6°9	'408	W. B.
Σ 2022	16 9	63 6	141°0	2°56	1	6°2 9°8	'460	L.
O Σ 309	16 16	48 7	69°8	0°49	1	7°5 7°8	'427	B.
Σ 2049	16 24	63 50	205°2	1°33	1	6°5 7°5	'460	L.
Σ 3105	16 27	96 50	30°7	0°35	1	7°7 7°7	'465	B.
Σ 2084	16 38	58 14	174°4	1°01	2	3°0 6°5	'446	B.
	...	...	175°4	1°09	2	...	'546	L.
	...	...	178°6	1°21	2	...	'563	W. B.
Σ 2091	16 39	48 38	125°6	1°03	2	7°5 8°0	'701	L.
Σ 2097	16 41	54 5	86°0	2°04	1	8°5 8°7	'441	L.
De 15	16 41	46 21	294°6	0°60	2	8°2 8°6	'701	L.
Σ 2101	16 42	54 12	53°3	4°56	1	6°3 9°0	'441	L.
Σ 2106	16 47	80 26	300°9	0°35	1	6°7 8°4	'482	W. B.
Σ 2107	16 48	61 11	358°8	0°80	1	6°5 8°0	'460	L.
Ho 409	16 52	66 30	19°5	8°19	2	8°1 13°0	'447	W. B.
Σ 2118	16 56	24 50	85°9	0°35	1	6°4 6°9	'427	B.
Σ 2114	16 57	81 25	161°4	1°36	1	6°2 7°4	'482	W. B.
Ho 411	16 59	66 10	262°6	2°09	2	8°3 12°0	'451	L.
Hu 167	17 4	80 3	63°4	0°61	1	9°5 9°8	'460	L.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	h m	°	°	"				
	...	...	62.9	0.63	1	...	.482	W. B.
Hu 170	17 8	80 8	274.5	1.48	1	8.5 10.8	.460	L.
	...	...	274.0	1.93	1	...	.482	W. B.
Ho 414	17 19	63 50	95.2	0.72	2	8.4 8.8	.555	W. B.
Ho 415	17 19	64 10	329.3	1.30	2	8.0 8.7	.555	W. B.
Σ 2171	17 24	99 56	75.6	1.51	1	7.5 7.6	.580	B.
Σ 2173	17 25	90 59	318.7	0.55	2	6.1 6.3	.589	B.
Hu 179	17 27	78 43	50.3	2.24	2	8.8 8.9	.555	W. B.
Σ 2205	17 40	72 15	303.3	2.11	2	8.3 8.7	.467	W. B.
Σ 2215	17 41	72 16	292.0	0.77	2	5.9 7.9	.467	W. B.
Ho 422	17 48	95 18	20.8	0.58	1	8.2 9.0	.580	B.
Ho 424	17 54	61 44	210.2	1.44	1	8.0 11.0	.460	L.
Σ 2272	18 1	87 28	170.6	2.32	11	4.5 6.0	.595	W. B.
Σ 2283	18 5	83 52	87.0	0.82	1	7.2 7.7	.580	B.
Hu 314	18 5	71 23	142.5	0.38	2	8.3 8.5	.631	W. B.
Hu 315	18 5	66 27	54.7	0.52	1	9.3 9.3	.627	W. B.
Hu 316	18 6	71 45	151.0	1.72	3	9.0 10.1	.620	W. B.
Hu 317	18 7	72 48	20.6	1.88	3	8.5 8.8	.620	W. B.
Hu 196	18 10	81 3	345.3	0.45	1	9.0 9.2	.663	H. F.
Hu 319	18 13	67 13	79.6	0.25	1	9.2 9.6	.627	W. B.
Hu 238	18 18	80 6	344.9	1.46	1	8.6 9.2	.663	H. F.
Ho 83	18 20	62 32	274.5	0.61	2	8.8 8.8	.631	W. B.
Ho 84	18 21	62 37	316.6	3.88	1	9.0 11.0	.731	L.
Σ 2315	18 21	62 40	199.3	0.31	1	7.0 8.0	.731	L.
Hu 583	18 26	76 16	307.5	0.80	1	9.0 9.5	.663	H. F.
Hu 245	18 29	78 17	232.9	2.24	1	8.2 9.2	.663	H. F.
Hu 247	18 33	79 49	42.4	0.51	1	9.0 9.3	.663	H. F.
Hu 248	18 35	80 56	295.0	2.00	1	9.5 9.6	.663	H. F.
Σ 2367 AB	18 37	59 49	254.4	0.40	1	7.0 7.5	.808	L.
$\frac{AB}{2}$ & C	...	...	195.9	14.13	1	7.0 8.2	.808	L.
Ho 437 AB	18 37	58 27	297.6	0.44	1	8.3 8.5	.808	L.
AC	...	...	291.3	22.72	1	8.3 13.0	.808	L.
Dd	...	...	344.9	3.81	1	11.2 11.7	.808	L.
Hu 254	18 46	81 59	168.7	1.03	1	8.9 13.5	.736	H. F.
Hu 256	18 46	81 24	186.4	3.78	2	8.5 12.8	.700	H. F.
Hu 258	18 49	78 30	213.8	2.58	3	8.9 9.4	.629	W. B.
Σ 2422	18 54	64 1	95.7	0.88	2	7.6 7.7	.680	W. B.
Hu 330	18 55	70 31	31.7	0.77	2	9.0 9.3	.700	H. F.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Dist.	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
	^h ^m	[°] [']	[°]	["]				
Hu 678	18 56	77 54	363°1	3'04	3	8'0 10'5	'651	W. B.
Ho 92	18 57	57 37	34°0	1'33	1	9'0 9'1	'808	L.
Σ 2437	18 58	70 58	58°1	0'89	2	7'8 8'0	'681	W. B.
Ho 443	19 6	70 44	117°6	3'04	2	9'5 9'5	'700	H. F.
	...	...	117°9	2'77	1	...	'665	W. B.
β 1204 AB	19 7	87 32	8°7	0'32	2	7'7 8'5	'753.	B.
Σ 2476 $\frac{AB}{2}$ & C		...	213°7	31'08	2	6'2 11'0	'753 ₁	B.
Ho 445	19 9	65 34	244°8	5'18	2	9'3 10'2	'660	W. B.
Ho 446 AB	19 9	65 35	291°1	2'92	1	8'0 13'5	'736	H. F.
Ho 447	19 13	62 14	173°2	2'05	1	9'5 9'5	'665	W. B.
Ho 576 AB	19 16	83 21	181°2	3'59	1	7'0 10'7	'736	H. F.
Ho 105	19 18	73 31	187°5	2'56	3	8'5 10'0	'600	W. B.
Hu 339	19 21	71 32	47°0	0'50	2	8'6 8'6	'659	W. B.
Ho 451	19 23	62 18	297°0	4'14	2	9'3 11'0	'660	W. B.
Σ 2525	19 23	62 51	310°2	0'66	1	7'4 7'6	'682	W. B.
Hu 340	19 24	71 43	120°9	0'85	2	9'0 9'3	'659	W. B.
Σ 2536	19 28	72 25	79°5	1'78	1	8'0 11'0	'736	H. F.
Ho 274	19 31	73 45	74°1	3'75	3	8'3 11'0	'680	W. B.
Ho 110	19 35	71 31	78°9	2'50	2	9'5 9'5	'660	W. B.
Ho 112	19 37	71 35	79°4	2'65	3	9'0 9'0	'600	W. B.
Hu 1195	19 39	76 31	322°5	2'42	1	8'7 14'5	'736	H. F.
Hu 346	19 44	73 7	184°4	0'62	1	8'8 9'5	'736	H. F.
A.G.C. 11 AB	19 45	71 6	145°3	0'18	1	5'7 6'2	'810	B.
Σ 2596	19 50	74 58	320°6	2'12	1	7'2 8'6	'813	W. B.
Ho 583	19 55	68 8	252°6	1'59	1	9'0 10'7	'682	W. B.
Ho 584	19 57	64 3	228°7	2'05	1	6'5 12'0	'723	W. B.
Ho 118	19 59	56 35	26°7	2'73	1	9'1 11'0	'723	W. B.
Ho 591	20 14	62 23	292°1	2'14	1	9'5 10'0	'813	W. B.
Ho 457	20 21	60 55	60°8	2'21	2	8'1 8'1	'601	W. B.
Ho 130	20 23	53 6	106°3	2'51	1	8'5 8'7	'652	L.
Ho 131	20 24	71 32	326°1	4'82	2	7'8 11'2	'641	W. B.
Σ 2690 BC	20 27	79 3	234°5	0'27	1	7'5 7'5	'810	B.
β 151	20 33	75 43	100°3	0'15	2	4'7 6'1	'791	B.
Ho 458	20 35	61 10	279°8	1'98	2	9'0 9'1	'791	W. B.
Ho 144	20 48	70 13	167°7	0'42	1	7'0 7'0	'723	W. B.
Ho 150	21 4	71 31	135°1	2'69	2	9'0 11'5	'693	W. B.
Ho 151	21 6	86 31	192°0	1'78	1	8'5 8'5	'616	W. B.
Hu 767	21 9	74 24	157°5	0'25	2	7'0 7'0	'791	B.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° /	Position Angle. °	Dist. "	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
O Σ 535	21 10	80 24	212'2	0'16	3	4'1 4'1	'773	L.
	..	...	230'8	0'16	2	...	'791	B.
	...	...	227'7	0'24	2	...	'827	W. B.
Ho 284	21 12	74 24	89'0	3'57	3	9'0 9'3	'703	W. B.
Ho 154	21 14	59 48	208'6	3'61	1	7'8 11'0	'915	H. F.
Ho 155	21 16	57 8	35'8	2'37	2	8'0 9'5	'772	W. B.
Ho 157	21 19	58 22	23'1	3'80	2	7'7 7'7	'772	W. B.
Aitken 1219	21 21	60 8	124'3	1'33	1	9'3 9'4	'775	W. B.
Hu 276	21 24	82 40	26'7	0'85	1	9'3 9'7	'843	L.
Σ 2799	21 24	79 21	118'0	1'66	1	6'6 6'6	'843	L.
Σ 2804	21 29	69 41	155'4	2'97	2	7'3 8'0	'872	L.
Ho 161	21 28	50 20	359'5	2'50	1	7'0 11'0	'915	H. F.
Hu 371	21 31	65 57	169'9	0'22	1	7'0 7'5	'810	B.
Ho 164	21 37	55 20	66'6	3'75	1	8'0 8'1	'915	H. F.
Ho 166	21 40	62 34	73'9	0'31	3	7'5 7'5	'760	W. B.
	...	...	71'1	0'31	1	...	'862	L.
Σ 2822	21 40	61 39	124'1	2'22	2	4'0 5'0	'616	W. B.
β 989	21 41	64 46	104'5	0'27	5	3'9 4'4	'714	W. B.
	...	...	107'8	0'19	6	...	'821	L.
	...	...	108'1	0'49	1	...	'736	H. F.
	...	...	107'9	0'27	2	...	'791	B.
Ho 608	21 43	63 7	119'5	0'64	1	8'2 9'7	'862	L.
Ho 466	21 44	55 32	144'7	1'61	1	8'7 9'2	'915	H. F.
Ho 467	21 46	68 10	186'2	1'45	3	8'0 10'2	'689	W. B.
Ho 173	21 51	71 44	82'0	1'17	1	8'0 10'0	'843	L.
Ho 609	21 51	60 4	176'7	3'20	2	9'5 9'8	'794	W. B.
Ho 610	21 58	63 35	231'0	0'66	1	9'0 9'2	'862	L.
Hu 978	22 8	76 32	228'6	0'68	1	8'5 9'0	'819	W. B.
Ho 179	22 9	60 14	251'0	0'65	1	8'0 9'0	'819	W. B.
Ho 182	22 19	72 54	128'3	1'43	4	8'5 8'5	'809	W. B.
Ho 183	22 21	67 53	216'3	2'51	1	8'2 11'6	'843	L.
Ho 475 AB	22 29	64 3	317'6	0'89	2	8'0 8'2	'827	W. B.
Ho 294	22 33	63 2	62'9	2'10	1	8'0 10'0	'819	W. B.
Ho 296	22 36	75 56	68'5	0'32	2	5'5 5'5	'846	B.
Ho 190	22 45	62 28	153'7	2'03	3	9'2 9'2	'822	W. B.
Ho 482	22 47	64 5	73'0	0'14	1	6'8 6'8	'882	B.
Ho 484	22 54	69 44	108'5	3'19	1	8'0 12'0	'805	L.
Ho 192	22 55	60 24	29'7	1'82	2	8'5 8'5	'874	W. B.
Hu 398	22 58	71 53	323'8	0'37	1	8'7 9'0	'805	L.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° '	Position Angle. °	Dist. "	Number of Nights.	Magni- tudes.	Epoch 1906.	Obsr.
Ho 299	23 10	66 15	77°0	1'48	1	8'0 10'2	'835	W. B.
Ho 198	23 13	73 38	33'7	2'26	4	8'0 9'0	'856	W. B.
Ho 300	23 19	78 11	304'1	0'15	1	5'0 5'0	'882	B.
Ho 301	23 20	76 1	359'7	1'09	1	7'2 11'0	'835	W. B.
Ho 489	23 22	62 47	240'0	0'42	1	7'8 7'8	'835	W. B.
Ho 201	23 33	55 51	340'9	4'11	1	8'0 9'3	'915	H. F.
Ho 303	23 36	70 8	187'4	1'15	1	8'0 11'0	'862	L.
Hu 300	23 41	84 1	120'3	1'29	1	8'7 9'0	'882	B.
Ho 206	23 54	56 14	184'4	2'11	1	8'0 10'0	'928	W. B.

Royal Observatory, Greenwich :
1907 November 6.

Proper motions of 1186 Carrington Stars from a direct comparison between Carrington's Catalogue for 1855 and the Greenwich Second Nine-year Catalogue for 1900.

(Communicated by the Astronomer Royal.)

The proper motions of the following stars, which have been observed with the transit circle at Greenwich during the years 1897-1905, for the purpose of determining their places for use as reference stars on the astrographic plates, have been derived from a direct comparison with Carrington's Circumpolar Catalogue for 1855. For this purpose the places in Carrington's Catalogue have been reduced to the epoch 1900 by the ordinary trigonometrical formula with the Struve-Peters' constants, and in addition the systematic corrections given on p. 321 of *Monthly Notices*, lxvi. 5, have been applied.

Full details will be published in the Introduction to the Greenwich Nine-year Catalogue, 1900. The proper motions for both R.A. and N.P.D. are given in arc, and arranged in Zones of N.P.D.; the magnitudes are taken from the Harvard Photometry (marked *) and the Bonn Durchmusterung.

ZONE 0°.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "°cor.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "°cor.			
		R.A.		R.A.		N.P.D.				R.A.		R.A.		N.P.D.	
		h	m	+	-	+	-			h	m	+	-	+	-
201	9'2	1	45	...	0	7	...	h	8'9	11	35	...	25	...	13
303	9'0	2	32	...	3	...	22	i	8'8	12	42	...	20	2	...
b	8'8	3	19	...	3	...	40	l	9'0	13	51	3	...	7	...
538	9'2	4	28	...	18	...	4	t	9'3	15	29	...	5	...	31
d	9'1	6	39	...	27	...	4	r	9'3	15	55	10	...	...	9
e	9'1	8	30	...	17	...	22	n	8'7	16	9	22	...	7	...
g	9'0	11	0	...	83	...	31	3601	9'0	23	11	2	...	...	9

ZONE 1°.

Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.				Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.			
			Unit "/100.		N.P.D.					Unit "/100.		N.P.D.	
		h m	+	-	+	-			h m	+	-	+	-
23	8.8	0 16	...	8	...	2	1951	8.7	12 52	8	...	...	7
117	6.5*	0 56	68	...	31	...	1972	8.0	13 4	...	0	...	24
137	9.2	1 0	...	24	9	...	2048	8.5	13 27	...	2	...	31
183	8.0	1 18	24	...	18	...	2068	9.2	13 27	0	...	...	28
181	2.1*	1 22	36	...	...	0	2333	8.0	15 5	16	...	...	24
251	8.2	1 50	36	...	13	...	2494	9.0	16 6	20	...	...	2
263	8.8	1 56	51	...	31	...	2639	8.8	17 6	...	2	...	39
284	8.0	2 14	...	23	33	...	2740	9.0	17 32	8	...	...	7
305	8.8	2 17	...	175	...	35	2762	9.0	17 42	...	14	...	43
331	9.0	2 35	0	...	29	...	2793	8.5	17 52	9	...	...	24
347	8.5	2 42	5	...	38	...	2770	8.0	17 54	12	...	...	11
375	8.7	2 52	25	...	35	...	2942	8.8	18 49	...	9	...	17
412	9.0	3 5	...	0	...	2	2936	9.0	18 58	...	8	...	15
545	8.5	4 5	...	35	...	9	2976	8.8	19 11	4	...	...	11
739	8.8	5 47	...	18	28	...	3058	6.5	19 23	...	16	...	9
763	8.8	5 50	...	6	...	7	3082	8.0	19 43	...	8	...	11
823	9.0	6 18	...	18	22	...	3060	9.0	19 45	...	22	...	167
1035	7.0*	7 58	...	24	...	20	3106	8.8	19 54	9	...	...	4
1089	9.2	8 8	...	31	39	...	3138	var.	19 59	147	...	...	81
1095	9.2	8 19	...	26	20	...	3193	9.0	20 33	...	4	...	46
1336	9.1	9 27	...	25	17	...	3241	9.0	20 51	9	...	...	4
1490	8.5	10 19	...	29	...	2	3411	8.6	21 57	8	...	17	...
1639	7.4*	11 4	4	...	...	4	3465	8.7	22 12	...	18	18	...
1834	6.3*	12 14	...	27	...	65	3670	9.0	23 44	...	9	0	...
1922	9.0	12 46	...	37	...	35							

ZONE 2°.

3709	8.8	0 0	...	17	...	22	758	9.0	5 31	...	1	50	...
11	9.0	0 7	...	31	...	4	783	7.9	5 46	...	14	65	...
54	8.8	0 27	29	...	...	28	956	5.2*	6 54	...	39	33	...
140	8.8	1 0	1	...	26	...	871	8.9	6 24	...	29	...	4
191	9.1	1 21	24	...	60	...	903	9.3	6 35	...	12	7	...
267	9.5	1 54	...	3	18	...	897	8.5	6 35	...	14	46	...
369	9.3	2 47	...	17	...	19	997	8.5	7 17	...	51	48	...
394	9.0	2 50	...	31	...	19	1049	9.0	7 34	...	6	...	50
393	8.9	2 50	...	49	...	39	1193	8.8	8 26	...	37	30	...
406	8.7	2 59	21	...	39	...	1194	9.1	8 27	...	20	...	2
533	9.2	3 54	7	...	...	26	1183	9.1	8 27	...	46	...	9
619	9.0	4 36	...	21	15	...	1241	9.0	8 50	...	31	...	11
699	9.4	5 2	...	1	26	...	1330	8.0	9 18	...	53	37	...
707	9.3	5 9	...	16	0	...	1361	8.5	9 28	10	...	...	28

ZONE 2°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
1398	8.9	9	40	...	60	13	...	2564	9.1	16	48	...	16	...	50
1418	7.7	9	44	...	47	33	...	2590	9.1	16	56	12	...	2	...
1460	8.5	10	4	...	44	20	...	2600	9.1	17	1	...	10	21	...
1617	9.4	10	56	...	11	...	20	2735	8.9	17	47	...	23	...	11
1636	9.5	11	0	8	...	...	2	2769	8.1	18	4	29	...	...	2
1777	9.0	11	54	...	7	24	...	2819	9.0	18	17	16	...	4	...
1778	8.0	11	55	...	29	...	2	2959	8.0	19	15	21	...	15	...
1816	8.2	12	8	...	17	...	15	2973	8.0	19	16	6	...	...	4
1896	9.1	12	41	...	7	...	7	3076	8.9	19	54	23	...	15	...
1898	8.9	12	42	5	...	17	...	3078	9.0	19	57	...	20	24	...
1943	8.4	12	58	...	41	...	69	3160	8.0	20	25	6	...	20	...
2031	8.8	13	25	6	...	20	...	3215	9.2	20	48	87	..	...	127
2058	9.0	13	35	...	10	0	...	3267	9.1	21	12	7	...	...	4
2097	9.0	13	47	...	21	2	...	3270	8.0	21	16	31	...	...	9
2121	8.6	13	54	...	0	0	...	3376	8.8	21	49	44	...	...	7
2116	8.7	13	55	...	10	20	...	3400	8.2	21	59	17	...	...	11
2184	8.5	14	18	...	21	...	24	3450	9.0	22	22	...	25	22	...
2316	7.2*	15	9	3	...	...	28	3466	7.4*	22	24	30	...	2	...
2363	7.9	15	27	...	57	...	6	3479	9.2	22	36	3	...	11	...
2398	9.1	15	37	...	16	2	...	3660	8.5	23	43	20	...	2	...
2471	8.9	16	5	...	28	...	13								

ZONE 3°.

3714	9.0	0	2	290	...	32	...	537	8.9	3	53	...	27	...	11
13	8.9	0	9	152	...	...	4	548	9.0	3	54	6	...	65	...
15	8.8	0	9	2	...	...	32	635	9.2	4	35	8	...	...	13
18	9.2	0	10	...	30	...	24	640	8.3	4	38	...	47	...	20
56	9.0	0	27	...	12	...	6	662	8.0	4	46	...	4	24	...
85	8.6	0	37	...	28	9	...	670	8.7	4	51	...	16	...	2
113	8.8	0	49	318	...	...	108	797	8.8	5	47	18	...	...	4
145	6.4*	0	59	52	...	2	...	842	6.6*	6	8	18	...	106	...
151	9.0	1	2	4	...	...	2	889	8.9	6	23	...	24	9	...
173	8.8	1	11	...	30	...	15	917	9.0	6	35	...	16	13	...
236	8.8	1	40	29	...	0	...	958	8.5	6	50	...	30	37	...
242	9.3	1	42	...	4	...	9	1002	9.2	7	10	...	10	...	35
334	9.0	2	25	...	8	...	7	1005	8.2	7	11	...	95	165	...
352	8.6	2	32	...	46	...	26	1097	8.7	7	47	...	39	2	...
364	9.2	2	37	...	49	...	15	1190	8.5	8	19	...	14	13	...
435	8.8	3	5	16	...	18	...	1290	9.0	8	59	...	12	...	7
491	5.9*	3	34	140	...	70	...	1376	8.5	9	29	...	44	...	45
497	9.3	3	37	...	8	...	4	1458	8.6	9	58	...	4	...	17

ZONE 3°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
1494	8.8	10	10	...	44	2	...	2484	9.0	16	20	12	...	...	30
1519	8.4	10	19	...	24	...	2	2517	8.7	16	35	4	...	...	26
1620	9.0	10	54	...	43	...	4	2541	9.1	16	45	...	18	30	...
1633	8.3	10	57	...	8	...	4	2579	9.4	16	59	...	14	...	28
1645	7.2*	11	2	...	32	...	4	2606	8.5	17	12	...	35	...	41
1669	8.9	11	13	...	10	68	...	2670	9.2	17	32	...	43	...	67
1683	9.0	11	17	...	4	...	4	2673	8.5	17	33	...	35	...	71
1712	7.4*	11	28	...	12	...	74	2755	4.5*	18	5	25	...	...	50
1749	8.2	11	40	...	16	...	2	2771	5.9*	18	8	69	...	11	...
1756	8.9	11	44	...	29	...	13	2811	8.2	18	26	0	...	...	17
1762	8.8	11	47	...	263	...	239	2852	8.8	18	41	5	...	...	15
1787	9.0	11	57	...	88	...	0	2882	6.8*	18	48	2	...	...	27
1793	6.4*	12	0	...	68	...	94	2881	9.0	18	49	2	...	0	...
1812	8.5	12	7	...	20	...	2	2906	8.8	18	58	...	5	30	...
1830	6.4*	12	14	262	...	2	...	2953	9.0	19	16	...	12	...	15
1875	7.1*	12	35	...	32	...	2	2966	8.8	19	20	15	...	...	37
1944	7.8*	13	0	...	18	...	11	3015	9.0	19	41	6	...	...	2
2015	8.9	13	20	...	24	...	21	3055	8.7	19	57	2	...	...	11
2027	9.0	13	26	...	10	11	...	3240	8.9	21	6	20	...	...	7
2075	9.0	13	40	47	...	...	177	3260	9.0	21	16	...	24	2	...
2106	8.5	13	51	28	...	20	...	3273	7.4*	21	20	24	...	...	11
2109	8.5	13	55	...	25	...	30	3347	8.2	21	46	6	...	...	20
2122	7.4*	13	59	...	28	...	15	3351	8.7	21	48	135	...	...	56
2145	8.8	14	7	15	...	2	...	3352	8.5	21	48	136	...	...	75
2198	8.5	14	30	25	...	33	...	3353	8.3	21	48	4	...	2	...
2231	9.0	14	41	...	25	0	...	3452	9.0	22	24	...	8	18	...
2253	8.6	14	48	...	25	2	...	3493	8.0	22	42	...	15	...	0
2258	7.0*	14	50	...	15	0	...	3494	8.7	22	43	20	...	24	...
2301	8.8	15	9	...	70	17	...	3619	8.0	23	28	...	45	...	31
2367	9.1	15	32	...	27	...	17	3621	5.6*	23	28	85	...	...	15
2400	9.2	15	44	29	...	...	54	3693	8.0	23	55	22	...	27	...
2463	9.0	16	12	...	19	...	15	3699	8.6	23	57	10	...	...	13

ZONE 4°.

52	8.3	0	26	37	...	18	...	265	9.0	1	49	...	26	...	7
63	8.8	0	29	47	...	...	4	283	7.7	1	59	...	26	...	91
101	9.5	0	44	...	8	9	...	337	8.6	2	23	50	...	29	...
133	8.9	0	56	...	21	2	...	357	8.9	2	32	8	...	...	11
131	4.6*	0	55	100	...	20	...	374	8.8	2	39	...	13	33	...
218	9.0	1	32	...	26	...	22	377	8.8	2	41	...	32	...	16
235	9.2	1	39	...	13	...	14	441	9.2	3	5	18	...	15	...

ZONE 4°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
505	8.5	3	38	13	...	...	22	1566	8.4	10	31	6	...	...	22
572	9.0	4	5	...	5	9	...	1585	8.2	10	41	...	131	11	...
575	6.7*	4	6	8	...	...	31	1613	9.2	10	50	...	24	7	...
603	9.0	4	17	5	...	18	...	1615	8.9	10	52	2	...	2	...
611	8.5	4	21	11	...	44	...	1700	7.4*	11	24	...	11	...	42
642	9.0	4	34	41	...	160	...	1745	8.6	11	38	19	...	...	11
678	8.5	4	48	...	15	29	...	1757	9.0	11	45	...	78	...	33
698	6.6*	4	56	39	...	66	...	1759	8.4	11	45	...	18	...	22
704	8.5	5	0	...	8	128	...	1808	8.2	12	7	...	28	...	0
724	9.0	5	6	...	21	7	...	1809	8.9	12	7	...	31	...	13
727	6.7*	5	10	...	31	...	4	1813	9.0	12	7	...	61	11	...
770	6.4*	5	30	5	...	...	9	1849	8.4	12	20	...	8	...	2
782	8.0	5	35	...	15	...	18	1871	9.0	12	32	...	166	49	...
787	8.9	5	39	...	93	122	...	1905	8.8	12	45	...	148	...	17
788	9.2	5	41	...	18	7	...	1927	8.5	12	53	...	63	16	...
810	9.0	5	48	...	8	...	4	1928	8.9	12	53	...	106	0	...
876	8.9	6	15	...	11	22	...	1931	8.7	12	55	5	...	0	...
927	8.6	6	36	...	13	...	13	1942	8.5	13	0	...	65	...	9
933	9.0	6	36	2	...	11	...	1980	9.0	13	13	...	13	20	...
941	8.9	6	40	...	18	20	...	1999	9.0	13	18	...	28	2	...
957	9.0	6	46	8	...	13	...	2003	9.0	13	19	...	18	...	46
968	8.2	6	51	...	8	81	...	2001	7.4*	13	19	...	120	...	24
1057	8.5	7	27	...	13	24	..	2013	8.8	13	22	...	0	20	...
1064	9.0	7	30	...	26	...	24	2018	8.9	13	23	...	85	...	9
1123	7.3*	7	52	...	44	26	...	2038	9.0	13	30	78	...	77	...
1161	8.8	8	9	...	52	42	...	2045	8.0*	13	32	...	41	...	31
1167	9.0	8	9	...	13	...	18	2079	8.5	13	43	...	41	...	0
1196	9.0	8	21	...	91	195	...	2092	8.0*	13	51	...	39	24	...
1205	7.4*	8	25	...	107	103	...	2112	8.8	13	56	15	...	...	6
1213	8.2	8	28	...	19	9	...	2170	8.5	14	22	...	76	9	..
1240	9.0	8	38	...	67	2	...	2183	9.0	14	26	...	44	...	7
1259	8.0	8	47	...	59	...	15	2218	8.0	14	38	...	31	...	20
1268	8.2	8	48	28	...	...	13	2247	8.5	14	47	...	31	...	22
1277	9.0	8	55	...	35	...	0	2266	8.6	14	56	...	0	...	15
1320	8.5	9	9	...	11	...	31	2290	8.1	15	6	...	64	...	30
1357	8.5	9	20	...	2	22	...	2293	8.0	15	9	...	96	15	...
1472	8.9	10	2	...	20	...	4	2338	9.0	15	26	...	15	...	13
1478	8.7	10	4	...	28	...	24	2380	7.0*	15	43	...	8	55	...
1499	9.0	10	11	...	28	...	11	2382	7.2	15	43	...	2	...	33
1533	8.5	10	20	0	...	...	22	2395	8.8	15	47	...	33	18	...
1560	8.9	10	29	...	24	...	9	2403	8.8	15	50	28	...	...	28

ZONE 4°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
2423	7.1*	15	57	...	60	...	65	3141	8.0	20	27	...	58	34	...
2548	8.7	16	50	39	...	...	44	3200	8.0	20	50	40	...	...	38
2619	9.4	17	19	...	24	11	...	3218	8.8	20	59	247	...	73	...
2684	9.2	17	46	64	...	13	...	3232	8.1	21	7	13	...	...	18
2724	9.3	17	56	15	...	4	...	3277	9.0	21	23	...	13	...	13
2751	7.5*	18	7	...	2	...	9	3360	8.5	21	51	24	...	...	22
2804	8.7	18	28	11	...	18	...	3371	9.0	21	55	28	...	...	2
2809	9.3	18	30	...	11	33	...	3372	8.5	21	56	2	...	20	...
2907	8.9	19	1	...	8	0	...	3393	8.5	22	2	...	8	9	...
2926	9.0	19	10	...	13	...	11	3444	6.8*	22	22	39	...	...	7
2931	9.0	19	14	...	5	9	...	3441	5.4*	22	21	52	...	...	38
2989	8.4	19	34	50	...	...	78	3554	8.4	23	7	26	...	...	13
2990	8.9	19	36	79	...	...	2	3594	8.5	23	19	...	11	...	40
3067	8.5	20	3	...	32	38	...	3608	6.6*	23	24	...	24	...	31
3080	8.7	20	7	37	...	...	44	3615	8.0	23	26	...	19	22	...
3094	8.0*	20	14	...	28	...	213	3626	7.8	23	30	...	13	29	...
3099	9.0	20	16	15	...	9	...								

ZONE 5°.

3711	8.2	0	1	10	...	...	18	371	9.0	2	38	40	...	55	...
19	8.0	0	10	48	...	9	...	422	8.7	2	56	...	3	...	9
57	9.0	0	27	48	...	17	...	426	8.5	2	58	13	...	...	11
62	8.5	0	29	23	...	7	...	451	5.7*	3	9	89	...	155	...
65	7.8	0	30	10	...	27	...	489	8.9	3	30	...	3	7	...
67	9.0	0	31	58	...	...	38	496	8.4	3	32	...	22	...	13
69	9.2	0	31	78	...	16	...	503	9.0	3	35	...	35	20	..
89	9.0	0	38	35	...	...	9	509	8.8	3	38	...	19	7	...
95	8.8	0	41	19	...	2	...	518	9.0	3	41	...	19	2	...
104	8.2	0	45	6	...	...	16	591	7.4*	4	9	...	3	...	35
122	9.0	0	52	50	...	59	...	622	9.0	4	24	...	22	21	...
124	6.7*	0	53	68	...	9	...	643	7.7	4	33	3	...	9	...
157	8.8	1	3	29	...	20	...	692	9.0	4	51	29	...	...	15
169	9.0	1	8	...	16	...	15	705	8.8	4	58	49	...	155	...
190	8.8	1	18	114	...	37	...	748	8.9	5	17	3	...	33	...
225	8.0	1	34	10	...	0	...	784	9.0	5	37	6	...	...	9
227	9.0	1	35	35	...	61	...	799	9.0	5	44	59	...	...	172
247	8.9	1	41	0	...	20	...	812	8.9	5	46	...	32	...	16
260	8.1	1	46	13	...	22	...	821	9.0	5	49	...	32	89	...
306	9.1	2	6	...	6	13	...	826	8.8	5	54	29	...	36	...
314	9.0	2	10	0	...	...	4	872	9.4	6	12	0	...	...	28
328	8.5	2	20	88	...	90	...	929	8.2	6	34	...	89	...	70

ZONE 5°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
973	9.3	6	49	...	22	15	...	1965	8.8	13	10	13	...	0	...
1012	9.3	7	6	...	3	7	...	1975	9.0	13	11	16	...	...	11
1029	8.0	7	14	...	3	55	..	1995	8.5	13	17	...	16	...	22
1065	9.0	7	28	...	42	...	20	2006	8.0	13	20	...	96	...	37
1096	9.0	7	40	19	...	0	...	2014	8.8	13	23	...	62	...	6
1098	8.9	7	42	...	10	59	...	2093	8.8	13	53	...	10	...	20
1113	7.8	7	46	...	19	11	...	2165	8.0	14	22	...	10	...	4
1127	6.3*	7	53	...	42	26	...	2187	9.0	14	30	...	19	...	45
1153	8.8	8	2	...	22	13	...	2196	8.6	14	33	6	...	26	...
1184	8.9	8	14	...	19	...	26	2223	9.0	14	42	...	22	9	...
1188	8.3	8	15	...	10	28	...	2271	7.1*	15	2	...	19	...	11
1233	8.0	8	35	...	127	103	...	2283	8.4	15	7	13	...	0	...
1278	9.0	8	53	...	26	9	...	2288	8.9	15	8	19	...	73	...
1286	6.3*	8	55	6	...	...	20	2342	8.3	15	29	16	...	20	...
1296	8.6	8	57	...	23	4	...	2354	9.0	15	33	37	...	15	...
1347	8.0	9	15	10	...	18	...	2373	8.8	15	40	107	...	50	...
1379	8.5	9	24	10	...	44	...	2426	8.4	16	0	...	66	...	116
1393	8.3	9	31	...	22	22	...	2491	8.7	16	29	6	...	...	28
1399	8.7	9	32	...	16	2	...	2498	8.5	16	30	16	...	...	15
1397	8.8	9	32	6	...	...	31	2515	8.5	16	41	13	...	2	...
1402	8.7	9	32	29	...	11	...	2558	9.0	16	57	...	13	7	...
1410	8.0	9	35	...	16	7	...	2565	8.5	16	59	...	37	0	...
1414	8.5	9	37	16	...	...	26	2571	9.3	17	1	...	3	...	19
1442	8.8	9	48	...	29	...	2	2598	8.2	17	12	...	3	...	46
1451	6.5*	9	53	6	...	...	13	2642	7.7	17	29	35	...	31	...
1468	8.9	10	0	...	3	2	...	2655	8.8	17	34	...	10	18	...
1516	5.7*	10	15	...	104	38	...	2668	8.6	17	41	...	16	...	7
1529	8.5	10	17	...	68	40	...	2679	8.7	17	44	13	...	11	...
1540	7.4*	10	21	3	...	...	56	2693	8.9	17	49	29	...	...	35
1569	9.2	10	31	...	42	...	29	2698	9.2	17	51	6	...	...	4
1605	8.6	10	47	...	10	...	4	2743	9.9	18	6	32	...	...	50
1702	8.8	11	25	...	24	...	13	2746	8.2	18	7	22	...	...	28
1709	8.6	11	26	...	107	4	...	2744	8.4	18	7	22	...	24	...
1740	9.0	11	36	...	40	20	...	2778	9.0	18	20	...	48	2	...
1818	8.1*	12	9	...	10	...	11	2782	8.5	18	21	23	...	9	..
1829	8.5	12	14	...	48	2	...	2790	7.4*	18	25	10	...	...	7
1843	8.5	12	19	...	22	...	2	2810	8.5	18	32	26	...	...	80
1856	8.7	12	23	...	10	...	4	2817	8.5	18	34	16	...	9	...
1882	7.3*	12	38	...	220	...	20	2824	8.8	18	36	...	16	...	18
1945	8.6	13	1	...	16	133	...	2859	8.6	18	47	37	...	...	26
1956	8.6	13	5	...	45	20	...	2895	9.2	19	1	22	...	44	...

ZONE 5°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.				Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.			
			Unit		"cor.					Unit		"cor.	
			R.A.	N.P.D.	R.A.	N.P.D.				R.A.	N.P.D.	R.A.	N.P.D.
		h m	+	-	+	-			h m	+	-	+	-
2949	9.2	19 21	35	...	...	24	3262	9.3	21 20	...	3	32	...
2964	9.0	19 26	32	...	0	...	3285	9.0	21 27	...	22	50	...
2983	8.7	19 34	13	...	...	22	3382	9.0	22 0	...	29	0	...
3019	9.3	19 49	19	...	...	33	3422	8.0	22 14	39	...	...	65
3034	8.5	19 54	35	...	...	9	3436	7.5*	22 21	...	13	7	...
3043	8.5	19 57	88	...	...	57	3458	7.2*	22 27	45	...	...	14
3068	8.8	20 5	35	...	18	...	3509	7.1*	22 50	92	...	35	...
3091	6.6*	20 14	10	...	64	...	3520	6.2*	22 53	35	...	...	94
3120	8.5	20 23	20	...	...	22	3519	8.0	22 53	53	...	...	15
3123	7.2*	20 24	45	...	...	60	3634	8.7	23 34	42	...	4	...
3128	7.1*	20 25	...	81	0	...	3646	9.0	23 38	13	...	20	...
3188	9.3	20 47	...	19	15	...	3647	8.2	23 39	...	26	20	...
3205	8.4	20 53	3	...	48	...	3653	9.0	23 41	...	3	18	...
3237	9.3	21 9	...	10	4	...	3661	8.1	23 44	3	...	...	11

ZONE 6°.

2	8.5	0 4	58	...	2	...	485	8.2	3 23	9	...	18	...
10	9.0	0 7	156	...	28	...	504	7.5*	3 34	...	3	16	...
60	8.3	0 28	22	...	...	17	530	9.0	3 43	...	0	24	...
78	9.2	0 34	78	...	...	11	532	8.7	3 44	...	3	7	...
109	5.6*	0 45	63	...	28	...	565	8.8	3 58	...	22	...	24
115	9.1	0 48	49	...	...	11	571	8.7	4 1	...	19	...	4
174	9.2	1 9	15	...	...	2	580	5.4*	4 5	3	...	...	7
179	9.3	1 11	219	...	...	4	593	5.7*	4 8	...	49	...	95
206	8.9	1 24	22	...	...	4	596	8.7	4 12	19	...	26	...
233	8.9	1 37	...	85	...	2	618	7.4*	4 22	0	...	54	...
243	8.7	1 39	31	...	...	9	633	8.9	4 28	...	3	44	...
255	9.0	1 44	26	...	...	11	647	9.0	4 34	...	7	...	13
257	9.0	1 44	...	7	13	...	648	8.5	4 34	22	...	33	...
299	6.9*	2 1	49	...	38	...	654	8.5	4 37	...	27	...	13
316	8.9	2 10	12	...	18	...	657	8.8	4 38	...	19	9	...
332	8.0	2 20	...	19	...	11	669	8.5	4 42	12	...	18	...
342	9.0	2 23	...	26	...	2	691	9.0	4 50	...	19	...	22
354	9.0	2 28	...	56	...	37	725	8.7	5 5	0	...	50	...
363	9.0	2 31	...	22	7	...	726	9.0	5 5	22	...	...	4
411	9.2	2 51	51	...	...	28	732	9.0	5 9	...	48	24	...
427	9.2	2 57	19	...	...	4	738	7.3*	5 12	...	15	0	...
456	7.5	3 8	15	...	15	...	747	9.0	5 15	3	...	...	9
457	9.0	3 9	...	29	...	9	776	8.7	5 30	22	...	19	...
458	8.2	3 9	41	...	46	...	836	9.2	5 55	...	32	...	15
477	8.8	3 20	9	...	...	29	849	9.2	6 1	15	...	26	...

ZONE 6°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.				Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.			
			R.A.	Unit	"001.	N.P.D.				R.A.	Unit	"001.	N.P.D.
		h m	+	-	+	-			h m	+	-	+	-
852	9.1	6 5	.	7	11	...	1581	9.5	10 36	12	...	...	11
866	8.9	6 10	...	7	32	...	1583	8.6	10 38	...	7	...	4
908	9.3	6 25	...	12	9	...	1619	8.5	10 52	...	31	...	29
950	9.0	6 40	...	12	...	13	1641	8.2	10 59	...	87	20	...
953	8.5	6 41	13	...	245	...	1643	8.8	11 0	...	97	33	...
974	9.0	6 48	12	...	...	24	1665	9.0	11 9	...	44	...	15
979	8.9	6 50	...	7	24	...	1668	8.4	11 11	...	22	26	...
990	9.0	6 53	3	...	4	...	1704	8.8	11 25	...	34	...	4
1000	8.2	6 59	...	19	22	...	1746	8.4	11 38	...	15	4	...
1066	8.0	7 26	12	...	13	...	1761	8.0	11 45	...	15	15	...
1074	9.2	7 29	63	...	...	41	1763	9.0	11 48	...	92	20	...
1109	9.4	7 42	...	12	37	...	1766	9.0	11 48	...	10	...	28
1159	8.2	8 4	...	56	57	...	1771	8.5	11 52	49	...	37	...
1177	9.3	8 10	...	7	55	...	1780	8.7	11 54	..	34	2	...
1207	9.2	8 23	...	60	96	...	1781	8.8	11 54	0	...	33	...
1235	9.2	8 35	...	15	...	7	1790	8.4	11 58	15	...	...	15
1254	7.5*	8 42	...	3	...	2	1831	9.0	12 15	...	10	...	6
1262	7.1*	8 45	15	...	...	17	1833	8.7	12 16	...	26	...	9
1272	8.5	8 49	...	3	4	...	1836	8.1*	12 17	7	...	...	15
1289	9.0	8 54	...	15	2	...	1841	8.4	12 19	...	63	...	7
1298	9.0	8 57	...	26	...	17	1847	7.9	12 21	12	...	4	...
1297	9.0	8 57	...	19	...	4	1852	8.6	12 21	...	15	...	2
1316	9.2	9 3	...	71	51	...	1913	6.0*	12 48	...	27	...	49
1322	9.5	9 7	...	3	...	13	1914	5.1	12 48	...	27	...	42
1339	9.5	9 12	...	15	20	...	1916	8.5	12 49	..	15	...	17
1369	7.1*	9 20	...	12	11	...	1921	7.2*	12 53	26	...	...	35
1407	8.0	9 33	...	37	...	4	1925	8.8	12 53	...	15	...	6
1408	8.3	9 33	...	0	...	4	1937	9.0	12 59	...	41	...	2
1419	8.8	9 37	...	12	...	11	1938	8.3	12 59	...	27	0	...
1427	8.8	9 40	7	...	0	...	1970	8.7	13 11	...	12	29	...
1434	8.5	9 43	...	15	26	...	1969	8.9	13 11	7	...	6	...
1435	8.0	9 44	...	139	115	...	2022	8.5	13 26	...	22	...	17
1441	9.0	9 47	...	15	...	13	2023	7.3*	13 27	29	...	...	98
1470	8.9	9 59	...	7	9	...	2080	6.1*	13 45	46	...	44	...
1475	8.5	10 0	...	22	24	...	2105	9.2	13 56	...	26	...	49
1503	6.9*	10 12	15	...	11	...	2137	8.9	14 9	...	22	20	...
1518	8.6	10 15	3	...	...	20	2141	9.0	14 10	...	19	...	30
1523	9.0	10 15	26	...	4	...	2177	8.5	14 27	...	12	4	...
1537	8.4	10 18	...	7	26	...	2207	8.6	14 36	...	75	9	...
1538	5.4*	10 19	...	65	...	33	2206	8.5	14 36	...	26	...	93
1561	9.0	10 28	...	41	0	...	2244	9.0	14 48	22	...	...	11

ZONE 6°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.						Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.					
		h	m	+	-	+	-					h	m	+	-	+	-		
2281	8.8	15	7	12	...	...	4			2935	9.3	19	18	63	...	...	13		
2286	9.0	15	8	...	48	0	...			2965	6.4*	19	28	37	...	...	36		
2291	8.5	15	12	22	...	11	...			2971	9.0	19	30	31	...	...	4		
2296	8.8	15	12	...	77	...	43			3005	9.0	19	45	26	...	...	26		
2381	8.8	15	46	3	...	...	35			3004	8.3	19	46	3	...	...	0		
2387	8.9	15	47	19	...	0	...			3071	9.0	20	6	44	...	...	55		
2401	8.4	15	53	...	44	...	48			3072	8.6	20	8	61	...	40	...		
2404	7.3	15	54	26	...	2	...			3073	8.6	20	8	34	...	52	...		
2416	8.5	15	59	19	...	...	26			3077	8.5	20	10	31	...	...	9		
2418	8.5	16	0	...	3	...	46			3103	8.5	20	18	31	...	...	22		
2424	7.7	16	1	12	...	18	...			3132	9.0	20	27	15	...	20	...		
2448	8.2	16	12	3	...	...	9			3163	6.2*	20	39	38	...	15	...		
2501	7.1	16	34	3	...	...	13			3202	8.8	20	54	12	...	...	5		
2524	8.2	16	46	26	...	4	..			3216	7.7	20	59	43	...	...	94		
2557	9.0	16	58	...	12	...	11			3264	7.1*	21	22	41	...	13	...		
2599	8.8	17	15	0	...	...	17			3297	8.5	21	31	37	...	62	...		
2631	8.7	17	27	...	7	13	...			3309	8.6	21	35	19	...	2	...		
2633	9.0	17	28	7	...	2	...			3318	8.4	21	40	41	...	...	20		
2632	9.0	17	28	41	...	...	30			3334	8.8	21	46	...	12	22	...		
2647	8.3	17	32	19	...	...	11			3337	8.9	21	47	401	...	...	42		
2648	7.5*	17	33	88	...	...	103			3346	7.0*	21	50	102	...	...	20		
2729	8.8	18	2	...	7	...	35			3367	9.0	21	55	41	...	20	...		
2747	7.7	18	9	...	15	...	4			3386	8.2	22	2	7	...	...	0		
2779	7.8	18	21	...	9	31	...			3395	9.0	22	4	...	12	22	...		
2786	8.2	18	25	15	...	...	2			3416	9.0	22	12	3	...	...	24		
2788	9.0	18	26	...	15	...	7			3418	8.5	22	12	46	...	...	29		
2796	8.8	18	28	27	...	0	...			3438	8.3	22	22	298	...	...	5		
2802	8.5	18	30	...	3	...	27			3469	9.3	22	36	44	...	4	...		
2820	7.3*	18	36	19	...	...	38			3505	8.0	22	49	...	151	...	132		
2822	6.2*	18	37	19	...	28	...			3525	5.0*	22	55	129	...	...	29		
2870	8.8	18	53	53	...	44	...			3573	8.0	23	13	41	...	...	13		
2876	8.8	18	54	22	...	20	...			3628	9.2	23	33	194	...	...	22		
2884	8.8	18	56	34	...	...	11			3630	9.0	23	33	60	...	37	...		
2908	6.8*	19	4	31	...	24	...			3656	9.1	23	42	56	...	...	15		

ZONE 7°.

7	8.9	0	7	57	...	...	20	108	5.6*	0	45	14	...	...	14
16	9.0	0	10	...	4	...	16	116	8.5*	0	49	4	...	...	74
17	8.8	0	10	...	35	18	...	119	8.4	0	50	98	...	109	...
22	8.6	0	12	31	...	...	18	138	8.8*	0	55	61	...	0	...
61	9.1	0	28	22	...	...	27	155	9.0	1	1	0	...	2	..

ZONE 7°—continued.

Carr. No.	Mag.	Approx.	Proper Motions.				Carr. No.	Mag.	Approx.	Proper Motions.			
		R.A. 1900.	Unit	"oor.	N.P.D.	R.A. 1900.			Unit	"oor.	N.P.D.		
		h m	+	-	+	-			h m	+	-	+	-
189	9.0	1 15	18	...	...	11	1078	9.0	7 30	4	...	0	...
203	8.8	1 23	43	...	...	13	1108	9.3	7 41	...	4	...	22
205	8.6	1 23	0	...	2	...	1125	9.1	7 49	...	4	...	9
248	8.8	1 40	53	...	9	...	1144	8.3	7 55	...	61	7	...
274	8.4	1 50	0	...	...	11	1165	6.2*	8 5	18	...	25	...
310	9.2	2 7	...	8	...	2	1197	8.7	8 18	...	4	13	...
333	8.7	2 20	47	...	35	...	1211	8.5	8 23	...	14	7	...
344	9.2	2 23	8	...	...	31	1215	9.3	8 24	...	14	...	13
359	9.2	2 30	82	...	...	11	1220	8.7	8 27	...	22	24	...
423	8.0	2 54	43	...	...	7	1222	6.7*	8 28	...	8	7	...
438	9.0	3 0	31	...	42	...	1257	9.1	8 41	...	8	38	...
445	9.4	3 4	4	...	...	18	1274	9.2	8 49	4	...	7	...
459	9.3	3 11	22	...	...	7	1318	8.8	9 4	...	25	38	...
521	8.4	3 39	...	18	...	13	1341	8.5	9 11	25	...	58	...
541	9.0	3 46	8	...	27	...	1342	8.5	9 12	...	0	...	13
556	9.0	3 54	...	14	...	11	1360	8.7	9 17	...	25	36	...
601	9.3	4 12	18	...	...	4	1377	8.9	9 22	0	...	41	...
609	9.3	4 16	...	14	11	...	1387	7.5*	9 26	8	...	...	52
614	8.6	4 18	...	18	...	13	1392	8.8	9 29	...	53	18	...
687	8.6	4 48	...	43	4	...	1404	8.5	9 31	...	53	...	2
695	9.0	4 50	...	14	...	27	1424	9.2	9 39	...	8	...	2
711	9.2	4 57	...	8	46	...	1432	9.0	9 42	...	57	16	...
742	8.9	5 12	8	...	...	2	1474	7.6*	10 0	22	...	29	...
745	9.2	5 14	51	...	2	...	1500	9.0	10 9	...	59	...	4
774	9.0	5 28	22	...	...	7	1524	8.1	10 15	...	49	22	...
802	9.2	5 40	4	...	...	18	1521	9.0	10 15	...	4	4	...
800	7.6	5 40	49	...	...	42	1545	9.0	10 21	14	...	...	20
820	8.7	5 47	18	...	22	...	1547	8.9	10 21	...	78	29	...
879	8.5	6 14	4	...	13	...	1556	8.2	10 24	14	...	...	7
880	9.0	6 14	14	...	...	44	1562	7.7	10 28	...	39	34	...
898	9.0	6 20	69	...	137	...	1567	9.0	10 29	...	53	27	...
910	6.4*	6 23	8	...	28	...	1578	8.9	10 33	10	...	...	20
909	8.8	6 24	18	...	...	24	1623	8.8	10 52	14	...	...	16
944	8.7	6 37	31	...	...	44	1628	8.5	10 53	57	...	11	...
954	8.7	6 40	...	25	...	2	1650	9.0	11 2	...	18	...	20
972	9.0	6 46	0	...	2	...	1651	7.1*	11 2	...	120	168	...
992	8.0	6 55	14	...	...	4	1657	8.6	11 5	...	25	...	11
1017	9.0	7 5	...	35	2	...	1693	8.3	11 23	76	...	41	...
1027	5.0*	7 10	27	...	36	...	1731	8.0	11 33	18	...	24	...
1040	8.5	7 15	...	4	...	4	1742	8.6	11 37	...	53	...	16
1050	8.9	7 20	...	22	35	...	1747	7.7	11 38	22	...	...	9

ZONE 7°—*continued.*

Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.				Carr. No.	Mag.	Approx. R.A. 1900.	Proper Motions.			
			Unit	"	"	N.P.D.				Unit	"	"	N.P.D.
		h m	+	-	+	-			h m	+	-	+	-
1765	8.8	11 48	18	...	14	...	2451	9.0	16 14	25	...	38	...
1768	8.3	11 48	...	49	...	23	2461	8.5	16 19	25	...	9	...
1773	8.8	11 53	...	14	...	9	2475	8.7	16 23	0	...	...	18
1791	7.6	11 58	4	...	...	7	2479	8.0	16 24	...	8	...	31
1807	6.3*	12 7	...	14	7	...	2502	8.8	16 36	...	0	...	55
1810	8.9	12 7	22	...	...	38	2537	8.5	16 52	10	...	...	14
1854	8.9	12 23	18	...	13	...	2542	8.3	16 54	10	...	...	38
1859	8.0	12 25	...	67	...	16	2550	4.4*	16 56	...	10	...	0
1869	8.8	12 31	18	...	...	63	2552	9.0	16 57	31	...	27	...
1902	8.5	12 45	14	...	...	2	2575	9.0	17 6	8	...	2	...
1912	8.6	12 47	4	...	...	24	2587	8.3	17 10	0	...	18	...
1923	8.5	12 53	...	86	...	31	2592	9.0	17 13	8	...	...	4
1971	8.7	13 12	...	39	2	...	2595	9.0	17 15	22	...	...	9
1982	8.5	13 15	...	63	7	...	2624	8.5	17 26	31	...	...	7
1983	9.9	13 16	4	...	...	20	2638	8.5	17 29	18	...	...	27
1987	8.4	13 17	...	63	...	18	2650	9.0	17 34	...	18	...	44
2009	8.5	13 22	...	14	9	...	2651	9.1	17 36	8	...	9	...
2036	8.6	13 32	...	14	25	...	2662	9.0	17 39	61	...	31	...
2052	8.9	13 38	...	8	...	2	2713	9.0	17 58	31	...	...	9
2066	9.0	13 42	...	4	...	13	2717	8.8	17 59	0	...	22	...
2103	8.7	13 57	...	29	...	11	2741	8.3	18 9	43	...	4	...
2111	8.2	13 59	...	4	24	...	2772	8.7	18 20	31	...	18	...
2132	8.5	14 9	10	...	0	...	2780	7.3*	18 23	22	...	...	20
2152	9.0	14 18	10	...	4	...	2792	8.4	18 28	22	...	...	11
2157	8.5	14 19	20	...	36	...	2795	8.5	18 30	...	45	...	0
2186	9.0	14 31	...	22	...	11	2800	8.5	18 31	...	4	...	7
2193	8.7	14 33	...	29	...	82	2813	8.0	18 35	...	10	2	...
2222	8.5	14 43	14	...	20	...	2865	8.5	18 53	25	...	...	73
2232	9.0	14 46	...	25	22	...	2903	6.8*	19 5	25	...	...	30
2261	5.7*	14 57	153	...	232	...	2920	7.7	19 12	10	...	14	...
2263	9.1	14 59	...	4	...	9	2937	9.2	19 21	8	...	...	7
2289	8.8	15 11	8	...	...	33	2940	9.3	19 21	31	...	11	...
2328	8.8	15 26	...	39	...	7	2985	8.5	19 37	18	...	...	34
2343	8.2	15 32	204	...	...	25	3006	9.3	19 47	8	...	...	18
2360	6.9*	15 38	47	...	18	...	3036	9.3	19 57	0	...	...	4
2376	8.5	15 44	...	43	...	51	3041	7.6	19 59	10	...	...	34
2399	9.0	15 53	25	...	...	44	3081	8.5	20 13	...	35	...	79
2406	8.2	15 55	49	...	...	9	3133	8.1*	20 29	18	...	46	...
2410	8.6	15 58	...	22	...	0	3134	8.5	20 29	10	...	...	2
2437	9.0	16 6	14	...	...	132	3152	6.8*	20 34	14	...	...	5
2442	8.6	16 7	84	...	34	...	3186	8.6	20 48	39	...	...	32

ZONE 7°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "°oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "°oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
3189	5.7*	20	50	55	...	...	29	3527	8.5	22	57	22	...	...	7
3195	9.2	20	52	...	4	25	...	3552	8.1	23	7	31	..	...	25
3225	8.5	21	5	27	...	...	2	3564	9.2	23	11	...	49	...	11
3266	7.8*	21	23	49	...	...	100	3574	9.0	23	13	43	...	11	...
3283	8.0	21	28	10	...	11	...	3576	9.0	23	14	31	...	...	5
3291	8.6	21	30	22	...	2	...	3575	8.7	23	14	...	53	34	...
3301	8.8	21	32	...	10	2	...	3584	8.8	23	16	27	...	...	34
3323	9.0	21	42	...	14	39	...	3625	9.0	23	31	...	14	16	...
3343	8.5	21	49	22	...	...	9	3629	7.7*	23	33	18	...	7	..
3363	8.7	21	55	0	...	2	...	3639	9.0	23	37	14	...	...	2
3387	7.5	22	2	...	120	27	...	3641	8.5	23	37	...	4	14	...
3389	8.0	22	2	...	133	9	...	3652	8.2	23	41	...	4	...	16
3408	7.7	22	9	49	...	...	27	3659	8.8	23	44	157	...	7	...
3433	9.2	22	21	43	...	9	...	3662	8.5	23	45	18	...	...	2
3437	9.0	22	22	184	...	...	36	3673	9.0	23	47	22	...	7	...
3490	8.0	22	44	31	...	...	14	3681	6.6*	23	52	49	...	...	25
3502	5.0*	22	48	53	...	...	36	3700	7.1	23	58	...	4	...	5

ZONE 8°.

24	9.5	0	14	49	...	...	4	338	9.0	2	21	0	...	20	...
76	6.4*	0	32	...	100	...	91	346	8.4	2	23	20	...	...	4
83	8.6*	0	35	...	9	16	...	367	9.4	2	33	4	...	0	...
92	9.2	0	40	60	...	...	29	387	8.6	2	40	9	...	...	20
98	7.6*	0	42	...	29	...	4	392	8.5	2	41	60	...	20	...
130	7.5	0	53	9	...	...	9	429	5.9*	2	56	...	75	...	5
136	8.5*	0	55	...	175	66	...	453	7.3*	3	7	20	...	2	...
141	8.6	0	55	...	60	...	13	474	8.4	3	18	...	16	...	11
144	7.9*	0	56	20	...	...	13	480	9.0	3	21	16	...	...	26
161	8.6*	1	3	24	...	...	11	484	8.8	3	22	16	...	15	...
207	9.0	1	24	...	9	7	...	511	7.9	3	36	16	...	...	16
219	8.8	1	30	40	...	16	...	526	9.0	3	41	...	69	...	59
229	8.7	1	34	36	...	...	22	528	9.0	3	41	...	49	...	61
234	9.0	1	36	4	...	15	..	539	7.8	3	45	80	...	67	...
245	8.6	1	38	20	...	16	...	543	7.8	3	46	...	24	33	...
256	7.2*	1	44	44	...	...	4	577	7.3*	4	2	0	...	...	2
272	8.9	1	49	4	...	...	7	581	8.3	4	3	33	...	20	...
277	9.0	1	52	9	...	...	20	584	7.9	4	4	16	...	15	...
282	8.9	1	54	44	...	...	31	621	8.8	4	20	...	4	...	24
320	8.8	2	15	0	...	...	4	659	8.9	4	37	33	...	...	41
322	9.0	2	15	49	...	...	67	665	8.5	4	39	...	9	13	...
330	9.0	2	19	64	...	24	...	675	5.3*	4	42	...	16	...	42

ZONE 8°—*continued.*

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
681	8.4	4 44	...	4	...	9		1421	9.0	9 37	...	20	...	2	
685	9.2	4 47	9	...	125	...		1430	9.3	9 41	...	16	...	0	
720	9.2	4 59	40	...	0	...		1483	9.2	10 3	9	...	...	44	
722	8.7	5 0	4	...	4	...		1491	9.1	10 5	...	16	...	13	
750	8.6	5 14	102	...	134	...		1525	8.6	10 15	...	40	27	...	
762	8.6	5 20	...	4	...	18		1536	7.9	10 17	24	...	9	...	
790	8.5	5 35	...	4	...	31		1558	6.6*	10 26	...	24	2	...	
798	8.0	5 38	11	...	27	...		1577	8.4	10 32	...	60	...	25	
819	9.2	5 46	16	...	9	...		1622	8.8	10 51	...	11	4	...	
824	8.8	5 50	...	53	347	...		1637	8.2	10 57	...	206	62	...	
844	8.7	5 59	20	...	2	...		1652	8.2	11 3	...	40	7	...	
854	9.0	6 4	0	...	...	35		1663	9.0	11 7	...	16	...	33	
858	8.9	6 4	53	...	...	44		1671	8.3	11 11	...	40	27	...	
892	9.0	6 16	104	...	...	127		1691	9.0	11 20	4	...	...	16	
928	8.4	6 29	0	...	...	7		1698	8.0	11 23	56	...	...	47	
955	8.8	6 39	...	11	13	...		1707	6.1*	11 25	...	155	...	46	
976	9.0	6 48	24	...	9	...		1717	9.0	11 28	...	5	...	18	
980	8.9	6 49	...	24	20	...		1719	9.0	11 29	...	33	4	...	
1008	7.8	7 2	...	11	88	...		1721	9.0	11 29	...	133	73	...	
1018	9.2	7 5	...	4	...	4		1728	9.0	11 32	4	...	16	...	
1021	6.2*	7 6	9	...	26	...		1732	9.0	11 34	...	36	...	44	
1024	9.0	7 8	...	24	27	...		1741	8.5	11 36	...	40	7	...	
1045	6.5*	7 16	...	9	11	...		1769	8.9	11 50	...	16	...	7	
1077	7.6*	7 28	...	9	0	...		1772	8.8	11 53	...	36	2	...	
1105	7.1*	7 39	...	24	26	...		1774	8.0	11 53	...	71	50	...	
1128	8.7	7 50	...	9	26	...		1784	6.4*	11 55	...	75	32	...	
1131	9.2	7 51	...	4	...	13		1838	8.8	12 17	40	...	18	...	
1143	8.1	7 54	...	20	...	9		1845	8.5	12 20	...	24	...	9	
1209	9.5	8 22	...	9	7	...		1866	8.1	12 30	56	...	16	...	
1229	8.9	8 31	...	44	...	11		1889	6.3*	12 42	9	...	35	...	
1261	7.6	8 43	...	4	...	32		1915	9.2	12 49	...	93	...	55	
1265	8.6	8 44	...	20	7	...		1936	7.3*	12 59	...	69	2	...	
1291	7.9	8 53	...	31	43	...		1968	6.3*	13 12	0	...	...	11	
1295	8.4	8 53	20	...	26	...		1988	9.0	13 17	...	138	46	...	
1301	6.5*	8 56	...	20	24	...		1997	8.8	13 20	...	36	...	4	
1311	8.7	9 1	...	24	9	...		2025	8.5	13 28	...	4	...	24	
1325	9.0	9 6	20	...	24	...		2061	8.5	13 41	29	...	0	...	
1352	9.0	9 14	20	...	460	...		2064	9.0	13 42	...	53	9	...	
1365	9.0	9 19	...	24	16	...		2073	8.9	13 44	4	...	...	13	
1381	4.6*	9 23	...	29	...	2		2088	6.8*	13 52	51	...	2	...	
1394	8.9	9 29	...	49	...	29		2108	9.2	13 58	...	44	0	...	

ZONE 8°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
2135	8.8	14	10	16	...	...	2	2911	9.2	19	8	...	36	18	...
2171	8.6	14	27	...	64	...	22	2923	8.7	19	13	...	20	...	29
2176	9.0	14	28	...	4	...	31	2934	8.3	19	30	20	...	...	23
2188	7.1*	14	33	...	95	127	...	2947	7.9	19	24	67	...	...	43
2194	8.7	14	34	...	24	0	...	2948	8.0	19	24	20	...	...	18
2200	8.8	14	35	...	16	...	2	2960	8.8	19	27	20	...	5	...
2208	8.7	14	38	...	36	...	49	2962	8.0*	19	29	11	...	...	11
2230	8.9	14	46	49	...	...	00	2969	8.3	19	30	29	...	87	...
2252	8.6	14	53	4	...	42	...	2980	9.0	19	36	0	...	20	...
2256	7.2*	14	55	...	24	...	27	2995	8.8	19	44	...	20	14	...
2303	8.9	15	17	...	16	...	22	3031	7.7	19	56	31	...	...	70
2324	8.7	15	26	...	36	...	58	3049	8.6	20	3	44	...	...	22
2327	7.8	15	27	4	...	...	91	3054	8.9	20	4	16	...	...	27
2352	7.0*	15	36	0	...	...	34	3086	8.6	20	16	16	...	...	13
2358	8.5	15	39	4	...	4	...	3087	7.4*	20	16	31	...	...	41
2361	9.0	15	39	4	...	4	...	3140	6.9*	20	33	47	...	...	14
2392	8.4	15	51	...	80	...	74	3149	5.6*	20	35	31	...	...	14
2393	7.4	15	51	...	16	7	...	3161	8.5	20	39	0	...	...	16
2421	8.0	16	3	...	29	...	7	3162	9.0	20	39	4	...	...	9
2447	9.0	16	12	...	29	...	86	3166	7.2*	20	42	71	...	...	41
2458	8.2	16	18	29	...	18	...	3203	8.9	20	56	16	...	18	...
2478	8.2	16	25	24	...	...	4	3217	8.0	21	1	20	...	...	14
2505	9.2	16	39	...	4	...	33	3235	8.8	21	11	51	...	...	38
2554	8.7	16	58	...	0	...	24	3236	8.7	21	11	16	...	5	...
2569	8.5	17	5	...	0	...	13	3261	7.8	21	22	4	...	...	38
2568	6.7*	17	5	36	...	...	29	3263	7.9	21	23	24	...	7	...
2581	9.0	17	9	...	11	...	38	3290	8.0	21	31	260	...	...	88
2591	8.3	17	14	...	0	...	69	3304	9.2	21	34	4	...	...	7
2629	8.6	17	29	20	...	...	29	3324	9.2	21	43	36	...	...	0
2641	8.8	17	31	36	...	...	20	3326	9.2	21	43	36	...	...	7
2725	8.9	18	2	0	...	...	94	3383	9.2	22	2	20	...	...	11
2726	8.7	18	3	24	...	9	...	3426	8.9	22	17	9	...	...	2
2730	8.9	18	5	29	...	...	32	3440	7.0*	22	24	84	...	...	72
2757	8.5	18	15	44	...	...	31	3459	8.5	22	29	16	...	2	...
2768	8.7	18	19	36	...	5	...	3472	8.8	22	37	...	4	2	...
2775	7.5*	18	22	33	...	...	18	3483	7.7	22	43	0	...	2	...
2808	9.2	18	36	24	...	40	...	3486	8.0	22	43	36	...	...	2
2840	9.2	18	45	0	...	14	...	3489	9.0	22	44	...	24	7	...
2854	9.1	18	50	4	...	...	18	3503	9.5	22	48	...	4	0	...
2863	8.2	18	54	9	...	27	...	3504	8.9	22	49	...	0	...	5
2868	9.0	18	55	16	...	2	...	3507	9.0	22	50	...	20	27	...

ZONE 8°—continued.

Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.				Carr. No.	Mag.	Approx. R.A. 1900.		Proper Motions. Unit "oor. R.A. N.P.D.			
		h	m	+	-	+	-			h	m	+	-	+	-
3514	8.0	22	54	36	...	9	...	3579	8.8	23	16	11	...	14	...
3538	8.5	23	2	...	11	27	...	3580	8.1	23	16	11	...	7	...
3553	8.7	23	8	20	...	18	..	3587	8.5	23	18	0	...	23	...
3555	8.3	23	9	109	...	4	...	3637	8.3	23	37	...	16	...	2
3561	8.0	23	10	95	...	...	90	3668	9.0	23	46	124	...	...	7
3562	8.5	23	11	51	...	...	9	3674	8.0	23	47	20	...	...	0

ZONE 9°.

1186	9.4	8	11	5	...	...	7	2029	8.9	13	30	9	...	...	36
1187	9.3	8	11	17	...	9	...	2039	8.9	13	32	...	5	...	16
1238	8.0	8	33	...	21	15	..	2050	8.7	13	37	...	69	...	29
1243	8.3	8	35	...	21	43	...	2065	7.2*	13	42	5	...	...	22
1349	8.6	9	12	9	...	...	9	2115	9.2	14	1	...	26	...	11
1374	8.5	9	20	...	5	...	13	2169	9.0	14	25	...	0	11	...
1386	9.0	9	24	17	...	7	...	2197	8.5	14	35	5	...	...	11
1444	8.1*	9	46	...	5	...	7	2199	8.5	14	35	12	...	14	...
1447	8.4	9	48	...	64	56	...	2214	8.9	14	40	...	21	...	13
1580	6.7*	10	33	21	...	...	11	2312	8.7	15	21	17	...	...	38
1586	9.0	10	38	5	...	4	...	2326	8.6	15	26	5	...	...	16
1606	8.9	10	45	...	21	7	...	2348	6.5*	15	34	...	199	...	125
1607	8.5	10	46	21	...	...	45	2350	8.3	15	35	...	190	...	114
1616	8.8	10	50	...	38	17	...	2370	7.0*	15	42	...	47	...	53
1646	8.6	11	0	...	64	...	22	2415	8.7	16	1	...	9	...	66
1733	9.0	11	33	...	31	5	...	2438	7.6*	16	7	...	31	...	40
1824	8.4	12	11	5	...	10	...	2452	8.5	16	15	...	17	50	...
1825	8.3	12	11	0	...	...	9	2489	8.5	16	29	21	...	...	22
1835	9.0	12	16	...	43	9	...	2644	8.5	17	33	21	...	...	33
1868	7.4*	12	31	...	111	9	...	2695	8.9	17	53	...	5	5	...
1907	7.6	12	46	...	12	23	...	2716	9.0	18	0	0	...	17	...
2030	9.0	13	30	...	73	22	.								

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK
WITH INEXPENSIVE APPARATUS.

A Lecture delivered by Professor George E. Hale, Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, at the Royal Astronomical Society, Burlington House, London, W., on Wednesday evening, June 26, 1907. (Plate 5.)

I have sometimes heard it said that the great cost of modern observatories tends to discourage workers with small instruments—observers who are no less interested in the pursuit of astronomical research than the astronomers in the large institutions. It seems to me that if there is any serious discouragement, due to this cause, of men who are engaged in original research with small telescopes and inexpensive apparatus, it is a question whether large observatories should be established. For at any period in the progress of observational astronomy there are two most important subjects for consideration. One relates to the accomplishment of a great amount of routine observation and the discussion of results, and the other relates to the introduction of new ideas and to the beginnings of the new methods which will make the astronomy of the future. I think we will all admit that the introduction of new ideas is quite as important as the prosecution of routine research; and that if any cause whatsoever tends to discourage the men from whom the new ideas might be likely to proceed, that cause of discouragement should be set aside if possible. And therefore I say, with all seriousness, that it is a fair question whether large observatories, with powerful instrumental equipment, should be established if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones. I think it can be shown, however, that the large observatories should be a help rather than a hindrance, at least by suggesting new possibilities of research, in which most valuable results can be obtained by simple means.

I am talking to-night, in purpose at least, to the amateur; but my definition of the amateur is perhaps a broader one than is generally accepted. According to my view, the amateur is the man who works in astronomy because he cannot help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind. The "amateur," then, is the person to whom I wish to address my remarks, whether he be connected with a small observatory in the capacity of professional astronomer, or working by himself with very simple instrumental means. But in speaking to the amateur I do not wish to deal with work that shall be satisfactory merely from the standpoint of instruction or

amusement. That is not my purpose. If it is possible to carry on research by simple means that shall really be important and useful, it is my hope to point out some such possibilities. But I do not wish to speak of any work except that of the first class, nor to recommend that any investigations should be undertaken with simple instruments that are not quite as important as other investigations which can be better undertaken with more expensive instruments.

The problem then becomes one of this character—to determine the relative advantages of large and small telescopes for different classes of research, and the possibility of constructing really powerful instruments at moderate expense. I cannot pretend to discuss all phases of this large problem; I shall mention only a few of them, and approach it from a single direction. But before taking up the details of this discussion, perhaps I may be permitted to say that the conception that is sometimes formed of the newer observatories, the idea that vast sums of money are expended, perhaps without the fullest sense of economy, is not always well-founded. For I am quite sure that if you would visit us (to take a single concrete case) in California, you would agree that we have considered the economical side of the question, that we have perhaps in some instances gone almost too far in our desire to save money for instruments of research, and to economise in certain directions where money can be saved. For example, you would find that our offices, our buildings, are of the simplest and least expensive character, while our instruments and machinery are as effective as we can make them. The great expense of such an observatory as the Solar Observatory on Mount Wilson does not depend in large degree on the cost of the instruments used for investigations of the Sun, but in surmounting the difficulties encountered in utilising a mountain site, deprived of the ordinary means of transportation, and in the construction of large equatorial reflecting telescopes for stellar work, which cannot be built cheaply if they are to be really efficient.

I wish now to come to the question before us, and to illustrate some of the advantages and some of the disadvantages of large and small instruments. Perhaps you will permit me, in showing the first slide on the screen, to say that I have some right to undertake a discussion of this sort, because I have viewed the subject from the standpoint of the man using small and inexpensive apparatus. In my first spectroscopic work, which was done in a room in my father's house, the instruments were of the simplest character, and largely of my own construction. Later, a small building was constructed for a concave grating of 10 feet focal length, and the apparatus, although powerful, was not expensive. Subsequently a tower and dome were added, and a 12-inch telescope was erected for photographic work upon the Sun. After the preliminary experiments had been completed, and the spectroheliograph had begun to take form, the possibility that its results could be greatly improved through the use of a larger telescope suggested itself, and

for this reason I made many efforts to acquire a large instrument for these solar investigations. The result, through the generosity of Mr. Yerkes, was the 40-inch Yerkes telescope, which proved to be very useful for the extension of the spectroheliograph work. The next slide shows the instrument, which you will see is a large and expensive machine. The question, then, comes right down to this point: What are the advantages of such a telescope compared with, let us say, a 6-inch equatorial or possibly a 4-inch equatorial? Is it possible with a 6-inch equatorial to do work comparable in importance with the work that can be done with a 40-inch equatorial?

The next slide will show that there was an advantage in passing from the Kenwood 12-inch to the Yerkes 40-inch, at least for the photography of the Sun. Very minute details of the flocculi were brought out which had not previously been known. But it may easily be shown that the advantages of the 40-inch telescope for most classes of solar work are due more particularly to its great focal length than to its large aperture.*

Let us take another illustration. Here we have a picture of the Moon made by Professor Ritchey with the 12-inch Kenwood telescope. You will notice that near the terminator is the crater Theophilus, which you will see again in the next slide as photographed with the 40-inch telescope. This photograph taken by Professor Ritchey is probably as good a photograph of the Moon's surface as has yet been made, and in this case the advantage of the 40-inch telescope is apparent.† But if we take another case, as illustrated in the next slide, it becomes obvious enough that for certain classes of work the Yerkes telescope is not well suited. Here is a picture made with the 40-inch of the Andromeda Nebula. You see how little it shows, since a long-focus telescope, unless of very great aperture, is not well adapted for the photography of faint nebulae. When we compare this picture with the next one, made by Professor Ritchey, with the 2-foot reflector (of 8 feet focal length), we appreciate immediately that the 40-inch, in spite of its great advantages for certain classes of work, is wholly unadapted for other investigations. As you know, a refractor of much smaller aperture and of shorter focal length would also give a photograph of the Andromeda Nebula far superior to anything that could be taken with the 40-inch.

If we look at the next slide, which shows Professor Barnard's 10-inch Bruce telescope when it was mounted on Mount Wilson, where he was using it to photograph the Milky Way, you will see an instrument that is very small and inexpensive as compared with the Yerkes telescope. It has a 10-inch Brashear lens of 50 inches

* So far as resolving power is concerned, an aperture of 8 inches would be sufficient to permit the smallest known details of the flocculi to be photographed.

† Here, again, the full visual resolving power is not utilised, but the great aperture is of advantage in permitting the large image to be photographed with very short exposures.

focal length and certain smaller cameras attached to the side of the tube. With such an instrument as this, superb photographs of the Milky Way, like the one illustrated in the next slide, can be taken, which are indispensable for investigations on the distribution of stars in this part of the heavens. Excellent work can also be done with a much smaller lens, provided with a very simple mounting.* A fine instance of systematic work with a portrait-lens is afforded by Mr. Franklin-Adams's photographic map of the northern and southern heavens.

It is hardly necessary to recall the fact that the 40-inch could not do this work at all. If we attempted to photograph the Milky Way with it, we might get a very small region on a very great scale, but to give us any notion as to the general distribution of stars in the Milky Way the 40-inch would be a total failure. However, if it were a question of studying some star cluster like the one shown in this slide, which would occupy a very small region indeed of the Milky Way, the 40-inch would enable us to pick out the separate stars, to study their individual phenomena, their changes in light and position, while such work could not be done on photographs taken with a portrait-lens.

I have shown these miscellaneous illustrations for the purpose of emphasising, what is perfectly well known to all of you, that each instrument has its particular fields of work, in which it can accomplish, or permit to be accomplished, various investigations which are not within the reach of other kinds of telescopes. But I now wish to discuss the question somewhat more specifically, and in doing so I shall confine myself almost entirely to observations of the Sun, although one might attack the subject from many other directions. The first point is this. Suppose one has a small telescope of 4 inches or 6 inches aperture and wishes to observe the Sun with it; and let us assume at the outset that he has no attachments whatever in the form of spectroscopes, but that he wishes simply to make direct observations of the Sun: Is there work for such an instrument at the present time? If you will examine the literature of the subject you may perhaps be surprised to find that many years have elapsed since very careful and extensive investigations have been made similar to those of Langley, which may be almost forgotten by many astronomers, but certainly are not forgotten by those of us who follow the Sun and are accustomed to the appearance of the spots when the definition is good. The next slide shows the well-known drawing of Langley's typical sun-spot. You will remember, if you have systematically observed the Sun, that every time the conditions become extremely good, the structure of sun-spots more and more closely resembles this drawing. This is a typical drawing; it does not represent any particular spot; it brings together observations of various spots; but in general the details of a sun-spot look very much

* Professor Barnard has illustrated in the *Astrophysical Journal* some of the admirable results he has himself obtained with a cheap "lantern lens" belonging to an ordinary stereopticon.

indeed like that drawing when the definition is good enough to show them properly. This subject has been greatly neglected for a long time, and it would well repay observers with large or small instruments to observe sun-spots, and to study many of the details of their structure which still remain obscure and difficult to understand.* Of course the question of the resolving power of the instrument must then be considered. A 4-inch telescope, capable of separating objects one second of arc apart, would not do for the very finest details in a sun-spot. According to Langley, the penumbral filaments sometimes exhibit structure considerably smaller than such a telescope would show; but a 10-inch or 12-inch telescope would show everything that has ever been recorded in a sun-spot, and there are many instruments of that size available for such observations.† Even a much smaller telescope, if carefully and systematically used, would contribute largely to our knowledge of sun-spots and of the structure of the solar surface. One might enlarge upon this subject, but time is hardly sufficient to permit me to do so.

Now let us consider the case of the prominences. If we have available a small spectroscope like that admirable little instrument designed by Evershed, or the one made by Thorp,‡ or a still simpler home-made instrument, and attach such a spectroscope to a 4-inch or 6-inch telescope, we have an almost ideal equipment for the observation of the solar prominences. As a matter of fact, an instrument like the 40-inch is wholly unsuited for work of this kind. You will easily see why. If you wish to observe the entire prominence, its image in the focal plane of the 40-inch telescope is usually so large that the slit cannot be opened wide enough to include the prominence without admitting too much light of the sky. Therefore, for a study of the general characteristics of prominences, the small instrument has a great advantage over the large one. It was practically out of the question with the 40-inch for us to do systematic visual work on prominences. When the conditions were peculiarly fine we could study the structure of certain prominences, and I never saw anything more remarkable than such details when they came out under the best seeing. But with the spectroscope available, and under ordinary atmospheric conditions, we could not make records of the general form and distribution of prominences that would compare in value with the records obtainable with small telescopes.

* For example, it would be of great interest to study the structure of the umbra, as seen through a minute pin-hole in the focal plane of a positive eyepiece, as Dawes did many years ago.

† It must not be forgotten that photography is still far behind visual observations in revealing the minute structure of sun-spots. It can hardly be doubted, however, that if only the umbra and penumbra were permitted to fall on the plate, and the exposure properly regulated, new and valuable results would be obtained. The amateur will readily find many opportunities for work in this field.

‡ I wish to call special attention to the solar spectroscopes and other inexpensive instruments made by Mr. Thomas Thorp of Manchester. One of these, a polarising helioscope, has done excellent service on Mount Wilson.

It has remained for certain amateurs here in England very recently to show that objects upon the surface of the Sun which escaped many of the earlier solar observers can be observed at any time when the conditions are favourable with a very small instrument indeed. For example, Mr. Buss and Captain Daunt, and, I believe, some others, have been observing the Sun with such instruments, and have been able to see upon the disk dark regions in which the D_3 line is strengthened, which I think have never been recorded before in a systematic way. Observations of the dark D_3 line upon the face of the Sun were formerly mentioned as unusual and rather remarkable phenomena, and certainly, so far as I have ever seen in the literature of the subject, the dark hydrogen flocculi were never recognised upon the Sun by the earlier spectroscopists; but they are seen, at times at least, by those gentlemen to whom I have referred. This I can make quite certain from my own knowledge, because on one occasion, when Mr. Buss had described one of the very peculiar dark hydrogen flocculi—flocculi of this type appear very much darker than the ordinary ones photographed daily with the spectroheliograph—I looked up our photographs of that date, and there was the image recorded by the spectroheliograph precisely as it had been described. So that if I had previously been a little doubtful as to the possibility of seeing these objects with such an equipment, I gave up all doubt after having made that comparison.* One might say that it would hardly be practicable to observe such phenomena in any satisfactory way with a large telescope. A small one is very much more advantageous for work of this kind. As soon as possible we are going to set up a small equatorial for the purpose of seeing these objects and comparing them with our photographs, after having derived the knowledge of the possibility of observing them from the work done by these men in England. But we will not undertake systematic work in this field, as I hope the valuable observations now in progress here will be continued. No records are made with the spectroheliograph of the D_3 image of the Sun at present. We have tried experiments, but so far they have not been successful. We ought to be able to photograph the Sun through the D_3 line, but we have not done it yet. The only existing records are those made by the members of the British Astronomical Association. These observations should be made in conjunction with other solar observations, as in fact is being done at the present time. The characteristics of the hydrogen lines are being observed at the same time that these D_3 images are being recorded, so that any relationship between the two may be discovered. I cannot dwell upon this very interesting subject. There is a great opportunity here for further work of high importance.

I must now pass to the question of sun-spot spectra. I need hardly tell those who are present that observations of sun-spot

* As I understand the matter, only the more conspicuous dark flocculi can be observed visually.

spectra made visually are sometimes far more valuable than those which can be made by photographic methods. Take, for example, the lines in the green region of the spectrum. This photograph will suffice to show them. Here is the *b* group in the spectrum of a sun-spot and also in the spectrum of the photosphere. We see in the spot a large number of fine lines, long ago observed by Young and Maunder, and now being studied with great care. All of these fine lines shown by a powerful instrument photographically can be seen visually with a small spectroscope attached to a 6-inch or probably a 4-inch telescope, and many other phenomena which cannot be photographed at all can be seen with a similar equipment. There is a certain advantage in observing such spectra with a larger telescope, provided that the spot under consideration is a small one. But if the spot is a fairly large one (and hitherto no one has had time to observe the spectra of small spots systematically), I think there is no advantage whatever in having a large telescope to form the image of the Sun on the slit of the spectroscope; it is merely a question of having an image of moderate dimensions upon the slit, and after that the spectroscope does the work. So that, so far as the spots actually under observation are concerned, a small telescope is quite as satisfactory as a large one for *visual* work on their spectra.

I will return in a moment to the question of the relative advantages of the photographic and the visual method of observing spot spectra; but I want to point out in passing that the 40-inch telescope has certain very definite advantages for work on the Sun. If one wishes to observe the spectrum of the chromosphere, for example, the advantages of great focal length immediately become apparent. The width of the spectroscope slit is essentially constant; the chromospheric arc must have a certain linear width on the slit in order to permit the base of the chromosphere to be observed; and consequently the spectrum of the chromosphere, as seen with the 40-inch telescope, is a remarkable sight, showing thousands of lines which do not come out with a small focal image of the Sun.

Here we have, then, an illustration of the advantages for certain purposes of considerable focal length. I think it is not so much a question of the telescope's aperture here, because we must not forget, in thinking of the optics of this question, that the brightness of the spectrum (for constant purity) is quite independent of the linear or the angular aperture of the object-glass that forms the image of the Sun on the slit of the spectroscope.* Perhaps it is well to bear in mind that the brightest solar spectrum one can get is obtained without any telescope whatever to form an

* When the focal length of the collimator is limited (as is usually the case in a spectroscope attached to an equatorial telescope), an increase in the angular aperture of the telescope permits the linear aperture of the spectroscopic, and consequently the resolving power and the brightness of the spectrum, to be increased up to a limit fixed by the size of the grating available. With a cœlostast telescope, however, the same conditions do not obtain, since the aperture of the spectroscope can be increased by merely increasing the focal length of the collimator.

image on the slit, but merely with a collimator of suitable angular aperture. But a large solar image is frequently advantageous, and an equatorial telescope of great focal length is necessarily an expensive instrument. The aperture in the case just mentioned is less important than the focal length; but even if the aperture were only 6 inches and the focal length unchanged, the tube must still be 64 feet long, and the mounting would cost no less than the mounting of the Yerkes telescope. So if we wish to have an instrument of great focal length, and yet keep down the expense to a reasonable figure, we must use a telescope of a different type. There are many other reasons why we should wish to use a fixed telescope for certain kinds of solar work, although I should be the last to admit that the 40-inch telescope is not an almost perfectly satisfactory machine of its kind. It has, as we have seen, inconveniences and disadvantages for some classes of work, but in other fields its superior qualities become more and more striking day after day as the observer learns to appreciate them. I only wish we could afford to have such a telescope (or even a much smaller equatorial refractor) on Mount Wilson, as it would be of great service for many purposes.

Now let us consider some of the possibilities of the fixed telescope; and let me show, for purposes of comparison, a picture on the screen of the Snow telescope which is now employed at Mount Wilson. Here is a cœlostast, with mirror 30 inches in diameter. After passing to a second mirror the light is reflected to a concave mirror of 60 feet focal length, which sends it back and forms a large image of the Sun within a laboratory. This is a very simple instrument indeed. The first cœlostast we set up on Mount Wilson was a small one used by the Yerkes Observatory party at the eclipse of 1900, and it was not originally arranged for work of this kind; so we simply built a wooden support for a second mirror, and with the aid of a 6-inch objective of 60 feet focal length we made a telescope which served admirably for our solar work until this one was put up on the mountain.

The next photograph shows the spectrograph used with the Snow telescope. It is of the Littrow or auto-collimating type, with slit and plate-holder at one end of a long tube and lens and grating at the other. Light from the solar image, after passing through the slit, falls on the lens 18 feet (its focal length) distant. The rays, thus rendered parallel, then strike the grating and are returned to the lens, which forms an image of the spectrum on the photographic plate, just above the slit (the grating being tipped back a little). Such an outfit (fixed telescope and spectrograph) is an extremely simple thing to build in inexpensive form. Cœlostasts, for example, are common nowadays for eclipse work. One might have a cœlostast with a mirror only 6 inches in diameter and a second mirror about 4 inches in diameter, and then perhaps a telescope lens of 4 inches aperture and 40 feet focal length. Such an instrument as that, which could be very cheaply built indeed, would give a large solar image, adapted for many kinds of solar work.

Let me show you in the next slide how we build our spectrographs in actual practice. This is the most powerful spectrograph in use in the laboratories of the Solar Observatory. Here is a little slit I bought from Hilger, the last time I was in London, for a few shillings. All other parts of the spectrograph, except a lens and grating, are of wood, built in a few hours by a carpenter.* The wooden support for slit and plate-holder stand on a concrete pier, and close an opening through a partition which forms one end of a narrow dark room. Eighteen feet from the slit, within the dark room, is another concrete pier. A sliding wooden support, carrying a lens, and a simple wooden mounting for the grating, stand on this pier, and complete the spectrograph. Owing to the scarcity of gratings, we are fortunate in being able to use one loaned by Professor Ames, of Johns Hopkins University. If we had no reflecting grating, we could buy a replica very cheaply from Thorp, or Wallace, or Ives,† which would give quite as good photographs as we obtain now (though the exposures would be longer, because of the smaller aperture). They might even be better, because our photographs of spot-spectra (made with the similar spectrograph of the Snow telescope) are not what they ought to be, or what I hope they will subsequently become. They would not stand comparison for a moment, so far as perfection of definition is concerned, with those magnificent photographs of the solar spectrum made by Mr. Higgs in the centre of Liverpool, under conditions which would ordinarily be called very bad even for a crowded city, with tram-cars constantly passing in front of the house. With a spectrograph of his own construction (except the grating), Higgs made the finest photographs of the solar spectrum ever produced; superior, as Rowland would have said, to the best photographs made by himself at the Johns Hopkins University. It is obvious that something other than an expensive instrument is required to make a good photograph. Mr. Higgs has the ability, which others may acquire, to obtain superb definition and exquisite photographs with very simple apparatus indeed.

With a spectrograph of 1 inch aperture and 10 feet focal length, used with a fixed telescope of 4 inches aperture and 40 feet focal length, one would be in a position to make good photographs of the spectra of sun-spots.

What, then, are the relative advantages of visual and of photographic work? The next slide shows some photographs. The upper one is the spectrum of the Sun and the lower one is that of a spot. These photographs are better than visual observations for the determination of the wave-lengths of unknown lines in spot spectra, simply because you can measure the position of a line on

* Except the plate-holder, which is of a standard make.

† As these are not reflecting gratings, the auto-collimating spectrograph might in this case give way to one in which a separate camera lens is used. With the angular aperture here considered, well-made simple lenses would obviously serve perfectly well for collimator and camera, the photographic plate being set at the angle required to bring a sufficient range of spectrum into focus.

the photograph to much better advantage than you can do it visually at the telescope. They are also better for the determination of the relative intensities of the lines, especially the fainter ones. But when you have said that, you have said almost everything that can be said for the photographs, and you have left out of account many of the very important advantages of visual observation. These photographs represent the integrated spot spectrum, as it were. Even with a large image of the spot on the slit of the spectrograph (and you realise here that the principal point of our great focal length is to have a large image of the spot on the slit), we cannot as yet satisfactorily record minute differences in the spectrum corresponding to small details in the spot. If we wish to study these very important differences in the spot, we must do so, at present at any rate, by visual means. For example, Mr. Newall, your President, told me the other day that he had found the spectrum of the outer edge of the penumbra of a spot to have the same characteristic strengthening of the lines that is observed in the umbra, which is a very difficult thing to explain from the standpoint of the hypothesis I have been favouring of late, viz. that the principal cause of the change of the relative intensities of lines in a spot is reduced temperature of the vapours in the umbra. I knew nothing about that; I had not been observing the spot spectrum visually for many years, and in our photographs this phenomenon is not recorded. You see, then, in such a case the decided advantage of visual observations. I might go on to speak of other advantages. For example, suppose there were a sudden change in the spectrum due to an eruption; the chances that one would get a photograph just at that time are small, whereas visual observations necessarily occupy a considerable period of time, during which eruptions might be detected.* Even a few results might be of extreme importance, and would probably be wholly missed in the photographs. Again, the extension of certain lines outside of the spot upon the photosphere is not recorded at all in our photographs, because of the method we usually employ of excluding from the plate all light except that which comes from the umbra, and perhaps part of the penumbra. We ordinarily get no trace of these extensions, but perhaps the conclusions drawn from the study of such phenomena may have much to do with the final views as to the nature of the spots themselves.

To mention only one other thing, the reversals of spot lines which have been seen by some observers have not been photographed with our present apparatus. Whether they can be photographed in the future remains to be seen. But, without going into this subject of spot spectra any more in detail, you will certainly agree that the visual observer has a superb opportunity, which the photographic observer cannot by any possibility take away from him.

* It is, of course, desirable to take photographs as often as possible, since a photographic record of a marked change in the spectrum, if fortunately obtained, may be much more valuable than the results of a few visual observations made hastily.

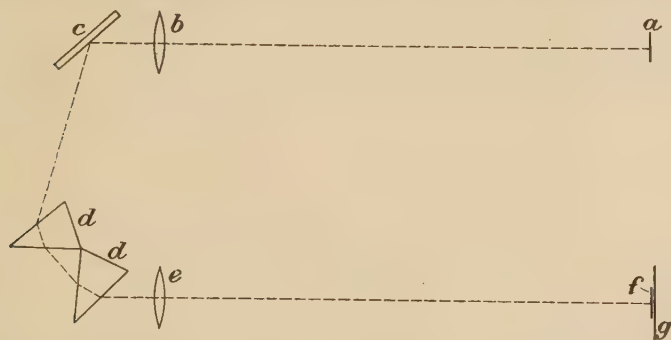
I now wish to speak rather more particularly of another phenomenon mentioned here the other night, which is peculiarly adapted for investigation with a small solar image. I refer to the differences between the spectrum of the centre of the Sun and the spectrum of the Sun's disk near the limb, as shown in the next photograph. Here is the spectrum of the centre of the Sun, and here is the spectrum of the Sun at a point a short distance inside of the limb. You will see at once the remarkable changes that take place. The broad H_1 and K_1 lines (or bands) are greatly reduced in width; and the same thing occurs. I think, in the case of all lines that are accompanied by wings. In this region of the ultra-violet many of these lines have wings, which are lost or greatly reduced near the edge of the Sun. This causes a remarkable change in the appearance of the spectrum. Several other curious things occur. Not only do these wings change in intensity very much, but the central part of the line, which seems to be sharply distinguished from the wings, undergoes a decided change of intensity also, so that we find from a preliminary examination of the plates that the lines that are strengthened in sun-spots are generally strengthened near the edge of the Sun, while the lines that are weakened in sun-spots are generally weakened near the edge of the Sun. This is true, I think, in the great majority of cases. Again, we find another curious thing: almost all of the lines derived from points near the Sun's limb are shifted towards the red in the spectrum with reference to lines from the centre of the disk. But there are some striking exceptions, and one of them is most significant: the lines in this fluting of cyanogen are not appreciably displaced. As we know from laboratory experiments that flutings are not displaced by pressure, whereas lines are thus displaced, we seem to have an interesting confirmation of the conclusion previously reached by Halm from his visual observations of two lines in the red—that the displacement of these lines is to be ascribed to pressure.*

This investigation is a many-sided one, with applications to both solar and stellar phenomena. There is room here for many investigators, who can obtain results quite equal, and very likely superior, in value to any we can get at Mount Wilson. A large image of the Sun is not required, because the effect is very appreciable at some distance from the limb. It is also a matter of no importance whether the definition of the solar image be good or bad. The one essential point is that the spectrograph be fairly powerful, and this is a very simple thing to realise at moderate expense. I hope to see this subject taken up by several observers, who will determine the shifts and the relative intensities of the Fraunhofer lines, seek for evidence of periodic changes, and work out an explanation of these remarkable phenomena which will harmonise with some

* This conclusion is further confirmed by the fact that lines of a given element, which exhibit unequal displacements at a certain pressure in the laboratory, in general show corresponding displacements near the Sun's limb. It remains to be seen, however, whether some other hypothesis may not be equally capable of accounting for the observed phenomena.

explanation of the relative intensities of the same lines in sun-spots and in the spectra of stars.

I may now touch upon another field of solar research, and consider the possibility of doing useful new work with the spectroheliograph, which is by no means so expensive and formidable an instrument as one might suppose. The slide shows the first spectroheliograph used on Mount Wilson, before we built the more permanent one now employed; and since the fact that we did substitute a permanent instrument for the temporary one might lead to the inference that the former did not give good results, I may add that the photographs made with the wooden instrument are even better than the later ones. They show only narrow zones of the solar surface, but for sharpness they have never been surpassed.* In the illustration the spectroheliograph is partly hidden under this spectrograph, and you can only get a rough notion of it. There is a rectangular wooden platform here mounted on a pier.



At each corner of the platform was screwed a small cast-iron block, in which a V-shaped groove had been planed. In each groove was a steel ball. A moving platform, also built of wood, carried the optical parts of the spectroheliograph and rested on these balls, so that it could be moved across the image of the Sun (formed by a coelostat telescope). The motion was produced by a small electric motor, belted with a piece of fish-line to this large wooden pulley, which drove a screw passing through a lead nut fastened to the movable platform. The screw was cut on a foot lathe and the nut cast on it. This simple mechanism provided the means of producing a slow uniform motion of this upper platform across the image of the Sun. The arrangement of the optical parts was precisely the same as in the Rumford spectroheliograph.

Looking at the instrument in plan, we have a slit here (a) through which the light passes. A very simple slit will do. This was an old one; I think it came from a portion of the old Kenwood

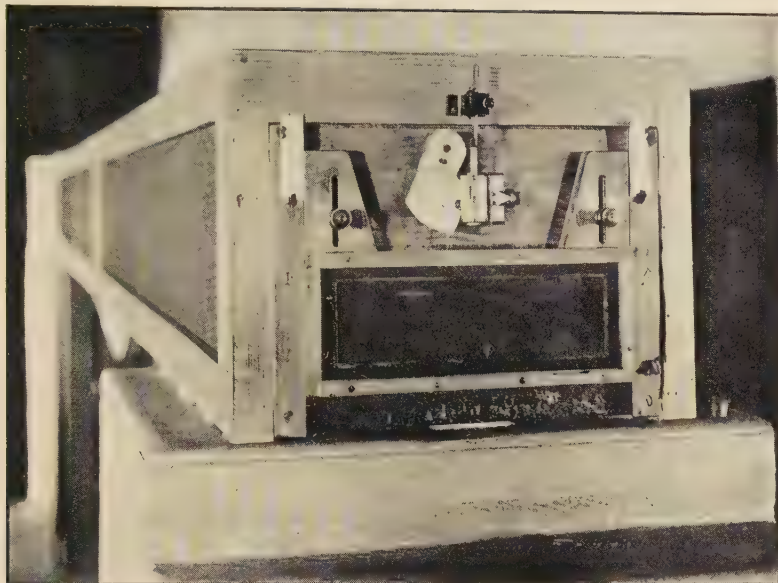
* In the 5-foot spectroheliograph now employed, the dispersion is great enough for photography with the hydrogen as well as the calcium lines. For this reason the exposures are longer, and the definition somewhat less perfect, though quite satisfactory for practical purposes.

spectroheliograph. The light passed through this slit and fell on a collimating lens (*b*), which may be an ordinary uncorrected lens if the focal length is sufficient. We happened to have some achromatics which we used, but they were no better than a simple lens would be. The parallel rays fell on a plane mirror here (*c*), and were reflected to these prisms (*d, d*). We used two prisms, but one will do perfectly well, unless hydrogen as well as calcium flocculi are to be photographed. These prisms had been discarded; they were originally made for the Bruce spectrograph, but they were so poor they could not be advantageously used, so we borrowed them from the Yerkes Observatory and put them in here. The two prisms, with the mirror, gave a total deviation of 180° . The light then passed through the camera lens (*e*)—here, also, a simple lens will serve very well—which formed an image of the spectrum on a second slit (*f*), close to the fixed photographic plate (*g*). By setting this slit on the H_2 line of calcium, and moving the instrument slowly across the solar image with the motor, excellent photographs of the calcium flocculi were obtained.

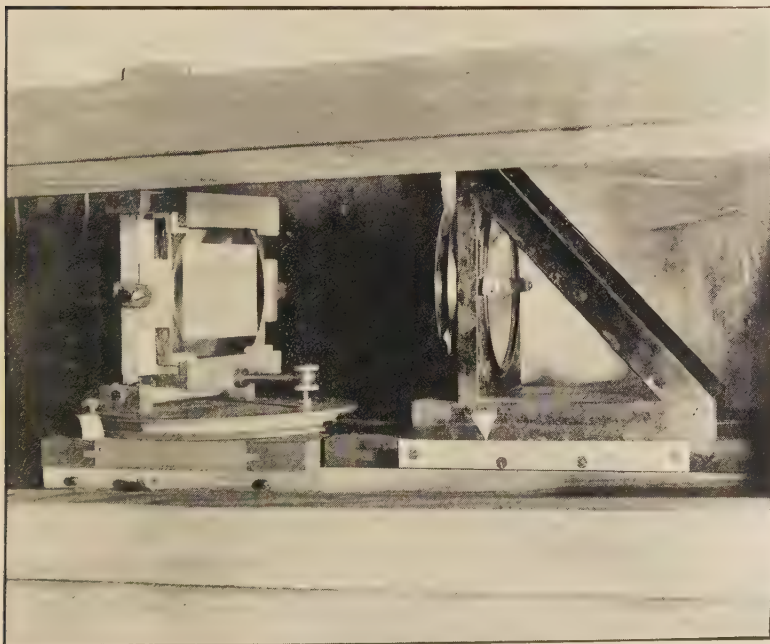
The next slide shows some photographs taken with the permanent instrument. Such photographs as these, made with the calcium and hydrogen lines, open up for investigation a large field, which anyone can enter with just such an equipment as I have described—a very simple instrument, with small prisms and lenses, and built almost entirely of wood.

I will show you in the next photograph some pictures obtained with the wooden instrument. You will notice that in this case the motion was not absolutely uniform; you can detect the slight irregularity of motion, but it did not affect the usefulness of the negatives. This is a direct photograph of the Sun; this is made with the H_1 line of calcium, and this is the same region as photographed with the H_2 line of calcium. If somebody would go to work with such an instrument and let us know exactly what such photographs as these mean, they would at least confer a very great favour upon me, because hitherto I have been unable to determine with certainty the relative parts played by the continuous spectrum of the faculæ and the light of the H_1 line of calcium in producing the photographs. That question is still open, and many investigations will be required to settle it beyond doubt.

In this H_2 photograph we probably have a picture of the calcium vapour at a higher level than the level represented by the H_1 plates. You see, for example, this bridge of calcium vapour across the spot, which is not shown by H_1 . Many investigations of great interest could be carried on with such a spectroheliograph as I have described. I wish I had time to go into them; there is only one I may mention, and that is the comparison of the calcium and the hydrogen images. Mr. Butler has asked me to explain to-night a point which I unfortunately failed to make clear in my talk here at the last meeting of the Society. In speaking of the relative level of the calcium and hydrogen flocculi, I said we found that the dark hydrogen flocculi are shifted somewhat towards the



Slit and plate-holder end of simple wooden Spectrograph of Littrow or auto-collimating type (18 feet focal length), used in the spectroscopic laboratory on Mt. Wilson [not the instrument referred to in the lecture, but a similar one, suitable for use in an open room].



Grating and lens supports for modern Spectrograph (18 feet focal length), used in the spectroscopic laboratory on Mt. Wilson. The bar for cutting off reflections from the lens is shown.

limb of the Sun as compared with the corresponding bright calcium flocculi. The natural conclusion to which I came was that the hydrogen absorption shown in this photograph is produced at a somewhat higher level, amounting to something like 1500 miles, than the calcium radiation which gives us this photograph. Mr. Butler pointed out to me that the photographs of the flash spectrum show the calcium vapour to rise to a higher level than the hydrogen gas, and that the difference is about 1500 miles. There is no question about the validity of this result, and the point is to show that it is compatible with my conclusion. I think the reason is simple enough, and lies in this fact: the flocculi photographed with the H_2 line do not represent the highest calcium vapour, but a level considerably below that; whereas the *absorption* phenomena known as hydrogen flocculi apparently represent the upper hydrogen in the chromosphere, or in some cases the prominences themselves. The level of the hydrogen absorption seems to be about 1500 miles higher than the region from which the H_2 light of calcium proceeds. If, as occasionally happens, the highest calcium vapour in the chromosphere is recorded photographically, it acts as hydrogen does, and gives dark absorption phenomena, due to the high level H_3 line, and not to be confused with the bright calcium flocculi due to H_2 . This point is perhaps a minor one, but it illustrates some of the results that can be obtained with a spectroheliograph.

I see that I must rapidly draw to a close. I might mention various other methods of employing spectroheliographs, and if anyone present should be interested at some future time to take them up I shall be delighted to discuss them in detail. I may remark in passing that with a Littrow spectrograph, or any long focus spectrograph, and a fixed solar image, one can undertake other work of various kinds, such as a determination of the solar rotation, along some such plan as Dunér or Halm followed, but using different lines in the spectrum, and benefiting from the advantages of photographic methods. In all such work, co-operation with other investigators is greatly to be desired, because it might otherwise frequently happen that two men would be doing the same thing, whereas it would be just as easy for them to supplement each other's work instead of duplicating it.

One other phase of the subject which I should like to have time to discuss, but cannot, is that of stellar spectroscopy. You will see that for stellar spectroscopy a large telescope in general does have an advantage. The more light one can collect and concentrate in a stellar image the more dispersion can be employed in the spectroscope, and the users of large apertures therefore do have an advantage in stellar spectroscopic work. But the fact remains that small instruments can be used to very great effect in this field also, provided that one intelligently plans his investigations. I know of no better example of this than one which I am permitted, by the kindness of Father Sidgreaves, to illustrate. Here is a photograph of the spectrum of α Ceti, made with a

refractor of 4 inches aperture, with a prism of $22\frac{1}{2}^{\circ}$ angle placed over the object-glass. The focal length of the telescope is 4 feet.

The slide shows the spectrum of Omicron Ceti on the 29th November 1905 and on the 1st December 1906, and brings out with great clearness the remarkable changes which occurred during that period. If this spectrum had been photographed with such an instrument, let us say, as the Bruce spectrograph of the Yerkes Observatory attached to the 40-inch telescope, there would have been some advantages, but there would also have been some disadvantages, because the entire region covered by the photographs made with that instrument (when three prisms are used) is a limited one here in the blue. All of these remarkable flutings in the less refrangible region would not have appeared in the photographs, and nothing would have been known, if one had been confined with such an instrument to a short region of the spectrum, about the very interesting changes shown in this particular case. The next slide shows another photograph taken by Father Sidgreaves, in this case with a somewhat different instrumental arrangement—a direct vision prism at the focus of a 15-inch equatorial. But you will see the great range of spectrum included on the plate, and remember again that almost all the spectrum, except a very small region, would be missing on photographs taken with such instruments as the Bruce or Mills spectrographs, or other three-prism instruments employed for the investigation of stellar motions in the line of sight. You will notice the remarkably interesting and important fact that the H_{ϵ} line of hydrogen is absent from the picture, probably, as Mr. Newall suggested, cut out by the absorption of the H line of calcium—the broad H_1 band; perhaps in another star lying nearer to us than the star which gives the bright lines of hydrogen. This serves to illustrate the great importance of the work that can be done with an instrument of very small size indeed, even in this field of stellar spectroscopy, which seems peculiarly to belong to telescopes of large aperture. As I said before, in general the investigator with a telescope of large aperture does have an advantage in stellar spectroscopic work; but there are various investigations of this sort—and of the kind Professor Pickering has taken up in his very extensive surveys of the whole sky with objective prisms—which are of extreme importance, and which cannot be replaced by work done with large instruments.

I might go on to speak of the possibilities of work on variable stars, but they are familiar to most of you. The observation of many wide double stars, my friend Burnham tells me, has been neglected since the time of Herschel, because the large instruments, and even the small ones, have been devoted to closer objects, so that in revising his great catalogue Burnham had to measure with the 40-inch a great many wide doubles which had not been looked at perhaps since Herschel discovered them more than a century before. Important double-star work is always open to men with small instruments, if a micrometer is available.

Then I might go on to the case where a man has no telescope at all, and still wants to make contributions to astrophysics. I do not now speak of such splendid work as Anderson did when he discovered Nova Persei with the naked eye; but if one were convinced that the overcast sky of London would never open again, he could still work in his laboratory and make important contributions by identifying lines and bands in spot spectra, as Professor Fowler has been doing of late, or by researches in a score of other fields.

I will close with a few practical suggestions. One reference to the matter of atmosphere. Perhaps some of us feel that if we could only ascend into the upper regions we could get results very much better than are obtainable in London. But if we stop to think of the men who work in London and what they have done, we must recognise the fact that even here the conditions are not so bad as we sometimes imagine. I have often been strongly impressed (since my work in Chicago) with the belief that a smoky atmosphere has some advantages in astronomical work, for it seems that the seeing is frequently improved in solar observations when the sky is smoky. Here is a fine chance to test that question, and I think it has been tested at Greenwich, and that some of the photographs taken there (both solar and stellar) prove that London smoke does not prevent excellent definition. I examined rather carefully some plates there yesterday, and the star images are surprisingly good in many instances. It seems to me that definition by night as well as by day at Greenwich must be of an order much higher than one might suppose when one thinks of Greenwich as being within the boundaries of London. But it is perfectly possible to get good results anywhere, provided sufficient care is taken. One must consider, for example, the best time of day for solar work. It usually happens that the best definition of the Sun occurs in the early morning and the late afternoon. Mr. Newall tells me that this is as true at Cambridge as it is at Mount Wilson. This is worth looking into if one takes up work on the Sun. Further, one must have a definite plan of work. This is of prime importance. Devote your entire attention to a single investigation, involving, if possible, two or three parallel series of observations, so devised as to throw light on one another. Frequently the value of a given series of observations may be enormously enhanced if other observations are available to aid in their interpretation. For example, in studying the spectra of sun-spots, the character of the spots, their motions, and changes of form, and the distribution of the flocculi in their neighbourhood, may be vital factors in interpreting the spectroscopic phenomena. Then, again, there is the great possibility that new methods and new instruments can be applied. Up to the present time I think the interferometers of Michelson or of Pérot and Fabry have never been systematically employed for work on the Sun: that admirable method which Fabry is using at the present time in the determination of absolute wavelengths would perhaps be very useful indeed if applied to the

measurement of the displacement of solar lines at the centre and at the limb. I also believe that the echelon spectroscope has never been used for the observation of the narrow bright lines in the chromosphere. Furthermore, we are always confronted by the possibility of perfecting our optical apparatus. I have been trying for years to get good prisms of large size, but cannot get homogeneous glass, and therefore it now seems necessary to attack the problem of fluid prisms. If someone could take that question up and show us how to make very large prisms that would be essentially perfect, they would accomplish a great advance. Lord Rayleigh told me the other day how he made some large fluid prisms that gave nearly theoretical resolution. By an extension of the same methods it seems likely that still larger prisms, suitable for the exacting requirements of photographic work, could be obtained.

And so I might go on pointing out opportunities of various kinds, but I should tire you if I ventured to do so. We must not forget, however, that the possibility always exists of getting some entirely new method that will be quite as important as any application of the interferometer, or the échelon, or other instruments to which I have called attention.

In concluding, I may add that we have made at the Solar Observatory a few drawings of some of these simple wooden instruments, which I shall be very glad to place at the disposal of anyone who might care to build instruments in a similar way.* They may serve a useful purpose by saving a certain amount of time.

I hope I have shown that it is possible not merely to do work of an inferior quality, but to do work of the first quality, with small or inexpensive instruments; work that cannot be duplicated or will not be duplicated with large instruments; in other words, that there is a splendid field for any man who wishes to accomplish results, wherever he may be situated, and however simple his means of research may be. I feel so strongly on this subject that I hope the suggestions I have made will not be entirely without effect. We need the ideas of men from all parts of the world; we need the contributions they can make; and we need them even more than we need larger instrumental means than we now possess.

* At Mr. Maw's request, a number of blue prints will be sent to the Royal Astronomical Society for convenient reference.

Errata in the Rev. T. E. R. Phillips's paper, Monthly Notices, vol. lxvii.

Page 524, line 8, for 1895-6 read 1905-6.

Page 526, line 31, for 1907 read 1906.